STEER PERFORMANCE AND INGESTIVE BEHAVIOR ON STARGRASS AND BERMUDAGRASS PASTURES

by

ASAMOAH LARBI

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To You and the "Kids"

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Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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By

Asamoah Larbi

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The beef industry in Florida is based on perennial grasses. Adapted grasses are needed to increase animal production in the region. 'Florico' and 'Florona' stargrasses (Cynodon nlemfuensis Vanderyst var. nlemfuensis) and 'Callie hybrid 35-3', an experimental bermudagrass, (C. dactylon (L.) Pers.) are superior in yield and persistence to the industry standard Ona stargrass (C. nlemfuensis Vanderyst var. nlemfuensis) under grazing in south Florida. Yet little information is available on forage production and animal performance on pastures of these three grasses. The objective of this study was to compare forage production, nutritive value, animal ingestive behavior and performance, and total nonstructural carbohydrate trends of Callie 35-3 bermudagrass, and Florico and Florona stargrasses under rotational grazing.

Seasonal herbage accumulation was greater on Florico and Florona. Concentration of crude protein (CP) did not differ between grass entries and ranged from 74 to 101 g kg^{-1}. In vitro organic matter disappearance (IVOMD) differed between grass entries ranging between 526 to 555, 566 to 571, and 520 to 533 for Callie 35-3 bermudagrass, and Florico and Florona stargrasses, respectively. Mean carrying capacity ranged between 1332 and 1573 steer d ha^{-1} and was greater for Florico and Florona than for Callie 35-3 bermudagrass. Total nonstructural carbohydrates in the root-crown region of all grass entries declined as the season advanced.

Average daily gain differed between grasses with a range of 0.30 to 0.48, 0.43 to 0.62, and 0.37 to 0.49 kg for Callie 35-3, Florico, and Florona, respectively. Beef gain ha^{-1} of 495 kg on Callie 35-3 pastures was lower than 751 and 655 kg on pastures of Florico and Florona stargrasses, respectively.

Herbage mass of the whole canopy and percentage of leaf in the canopy declined from d 1 to d 14 of grazing. The IVOMD of the Florico canopy was higher than that of Callie 35-3 bermudagrass and Florona. Bite weight, biting, and intake rate, CP concentration, and IVOMD of the diet selected by steers declined from d 1 to d 14 of grazing. Percentage leaf in the top canopy layer was positively related to bite weight, biting, and intake rate.

CHAPTER I
GENERAL INTRODUCTION

The beef cattle industry in Florida is based on perennial grasses. Bahiagrasses (Paspalum notatum Fluegge) are most commonly used for improved pastures; however, animal output from these grasses is low (Sollenberger et al., 1988). Therefore, efforts to increase beef production have concentrated on breeding, selection, evaluation, and release of cultivars that are persistent, high yielding, and of improved feeding value over standard cultivars.

Cynodons have demonstrated a high potential for improving animal performance (Adjei et al., 1980; Pitman et al., 1984; Bertrand and Dunavin, 1985). Forage production, persistence, and in vitro organic matter (OM) disappearance (IVOMD) of 'Florico' stargrass, 'Florona' stargrass (C. nlemfuensis Vanderyst var. nlemfuensis), and Callie 35-3 bermudagrass (C. dactylon (L) Pers.) were higher than the commercial cultivar, 'Ona' stargrass (C. nlemfuensis Vanderyst var. nlemfuensis), under small plot clipping and grazing trials (Mislevy, 1980; Mislevy et al., 1988; Kalmbacher et al., 1987). Similar in vivo OM digestibility and OM intake for Ona, Florico, and Florona stargrass hays by

steers were reported by Brown et al. (1988). However, daily gain of steers grazing Florico were 11% higher than that obeserve for Ona stargrass. These results suggest that Florico, Florona stargrass, and Callie 35-3 bermudagrass may have potential as conserved or grazed forage in south Florida.

Canopy structure and composition of temperate (Jamieson and Hodgson, 1979) and tropical (Chacon and Stobbs, 1976) forages may influence ingestive behavior and consequently animal performance under grazing. Measurement of ingestive behavior and canopy composition during grazing studies may help explain differences in animal performance.

Little information is available on animal performance, forage production, nutritive value, and ingestive behavior of rotationally grazed Callie 35-3 bermudagrass, Florico, and Florona stargrasses. This study was conducted to compare

1. Forage production, crude protein concentration, IVOMD, and seasonal total nonstructural carbohydrate trends of Callie 35-3 bermudagrass, and Florico and Florona stargrasses under grazing.
2) Average daily gain, gain ha^{-1}, carrying capacity, forage disappearance, forage allowance and utilization of Callie 35-3 bermudagrass, Florico, and Florona stargrasses under grazing.

3) Sward canopy composition and ingestive behavior of rotationally grazed Callie 35-3 bermudagrass, Florico, and Florona stargrass pastures.

CHAPTER II
LITERATURE REVIEW

General Description of Grass Entries

'Callie 35-3' bermudagrass (C. dactylon (L.) Pers.), and 'Florico' and 'Florona' stargrasses (C. nlemfuensis Vanderyst var. nlemfuensis) belong to the tribe Chloridae of the family Poaceae and genus Cynodon. Origin and characteristics of the grass entries are briefly presented in this section. For further details, readers are referred to Mislevy et al. (1989a, 1989b).

The experimental plant material that became Florico stargrass was introduced from Kenya into Puerto Rico in 1957 (Sotomayor-Rios et al., 1974). In 1972, sprigs were sent to Dr. E. M. Hodges at the Agricultural Research and Education Center (AREC), Ona, Florida. Florico stargrass was established into mob-grazing and grazing management studies in 1975 and 1980, respectively (Mislevy et al., 1989a).

Florico stargrass is stoloniferous and non-rhizomatous with erect culms 60 to 100 cm tall, hairy leaf-sheath, membranous ligules and leaf blades 7 to 23 cm long (Bogdan, 1977; Hall, 1978; Mislevy et al., 1989a). The inflorescence

is a single, spike-like raceme, produced mainly in fall and spring in south-central Florida (Mislevy et al., 1989a).

The experimental grass that became Florona stargrass was found growing in a bahiagrass (Paspalum notatum Fluegge var. saurae Parodi 'Pensacola') pasture at the AREC Ona on a site where sugarcane Saccharum and Hemarthria had grown (Mislevy et al., 1989b). Stargrass from the bahiagrass pasture was introduced into a Cynodon nursery in 1974 and into a mob-grazing study in 1975.

Florona is a stoloniferous, non-rhizomatous grass adapted to south-central Florida. It has a tufted growth habit, erect culms (60 to 85 cm tall) with leaf blades 5 to 12 cm long. The inflorescence is a spike-like raceme arranged in 1 or 2 whorls (Mislevy et al., 1989b).

Important attributes of Florico and Florona stargrasses are higher forage production, better forage quality than bahiagrass, persistence, and good growth in late fall and early spring (Mislevy et al., 1989a, 1989b). High hydrocyanic acid potential, high soil fertility requirements, and low forage quality after 6-wk of growth were listed by the same authors as disadvantages of Florico and Florona.

Callie 35-3 bermudagrass, an experimental, unreleased grass at this time, was developed by Dr. G. W. Burton in Tifton, Georgia, as a cross between 'Tifton 44' and 'Callie' bermudagrass. Callie 35-3 has both stolons and rhizomes and is a cold tolerant grass with erect culms 60 to 70 cm high.

It is highly productive and persistent in north and central Florida (Mislevy et al., 1988).

Forage Evaluation Schemes

Approaches to forage research and methods used are based on the types of problems involved. Rigid, standardized evaluation procedures may be less suited to a wide range of conditions and species. A clear definition of objectives is important prior to evaluating forages. This portion of the review describes three evaluation schemes (Mott and Moore, 1970; Myers et al., 1974; Mochrie et al., 1981) which, in the view of the author, could be used under diverse conditions with few modifications.

Mott and Moore (1970) outlined a five-stage forage evaluation scheme. The first two stages, I) screening breeder's lines and introductions in small clipped plots and II) uniformity testing and environmental evaluation, do not utilize the grazing animal to defoliate the plant. Stage III involves plant response to grazing management and fertility trials. In Stage IV product per animal and per unit area are determined. Stage V involves development of feeding systems. Quality evaluation using in vitro and in vivo digestibility procedures is recommended for Stages I to III and IV, respectively.

Major steps in the three-stage scheme proposed by Myers et al. (1974) are: Stage 1A) nursery rows; Stage 1B) second

year nursery rows; Stage 2A) grass-legume swards; Stage 2B) grass-nitrogen swards; Stage 3) grazing trial.

An extensive theoretical protocol for evaluation of new accessions was presented by Mochrie et al. (1981). Protocol A outlined development and evaluation of a new forage which consists of Phase I) collection of material and IVOMD determinations; Phase II) persistence and animal preference; Phase III) detailed management and qualitative animal response; Phase IV) seed increase or expanded vegetative source, and quantitative animal evaluation; Phase V) release and on-farm implementation and observation of herd or flock response; and Phase VI) refinement and continued improvement.

Protocol B proposed by the same authors for the evaluation of a modified cultivar of an established variety, had four phases: Phase I) productivity and quality (IVOMD); Phase II) persistence and animal preference; Phase III) seed increase or expanded vegetative source; and Phase IV) quantitative animal response. The scheme proposed by Mochrie et al. (1981) is more comprehensive and involves the use of grazing animals at a much earlier phase compared to Mott and Moore's (1970).

Response to Defoliation

Defoliation refers to the removal of plant shoots by grazing or clipping. It is better defined by its frequency,

intensity, uniformity, and timing in relation to the developmental phases of plants or swards (Harris, 1978). Defoliation is a major determinant of forage production, quality, persistence, and species composition of pastures. This portion of the review examines forage production and persistence of Callie 35-3 bermudagrass and Florico and Florona stargrasses.

Forage Production. There have been many investigations on the effects of defoliation on pasture production. Reviews (e.g., Younger, 1972) have concluded that more frequent and more intensive defoliation results in reduced forage production. Mislevy et al. (1988) conducted a grazing frequency study of seven Cynodon spp. at AREC Ona. Grass entries were grazed at 2-, 4-, 5-, and 7-wk intervals. Forage production of all grasses increased with decreasing grazing frequency. Callie 35-3 bermudagrass and Florico stargrass were superior in forage production to Ona stargrass. In other studies (e.g., Kalmbacher et al., 1987), Florico and Florona stargrasses were generally superior to Ona stargrass in forage production.

Ruelke (personal communication) evaluated 19 perennial grasses over a 6-yr period at Gainesville. Callie 35-3 bermudagrass produced more forage than Pensacola or 'Argentine' bahiagrasses (P. notatum Fluegge) in all years. Annual forage production of Callie 35-3 bermudagrass ranged from 11.6 to 21.4 Mg ha^{-1}.

Velez-Santiago and Arroyo-Aguilu (1983) studied the effect of three N fertilization levels (224, 448, and 896 kg ha^{-1} yr^{-1}), and three clipping intervals (30, 45, and 60 d), on forage production of five perennial grasses in Puerto Rico. Forage production of all grass entries increased with increasing N levels and clipping interval. Forage production of Florico stargrass was greater than 'Pangola' and 'Transvala' digitgrasses (Digitaria decumbens Stent). Rivera and Rodriguez (1980) noted that forage production of Florico stargrass was 5% lower than 'Bigalta' limpograss (Hemarthria altissima Poir. Stapf et C. E. Hubb.) under intensive grazing.

In the humid mountain region of Puerto Rico, Caro-Costas and Vincente-Chandler (1981), reported that carrying capacity on Florico stargrass pastures increased by 5% as grazing frequency decreased from 14 to 28 d. In another study, Caro-Costas et al. (1976) indicated that carrying capacity on Florico stargrass pastures was 17% higher than Pangola digitgrass. Rodriguez and Silva (1975) obtained greater forage production when Florico stargrass was cut at 5 to 10 cm stubble than when it was cut at a height of 15 to 20 cm stubble.

Regrowth of forage species after defoliation is an interdependent function of leaf area, food reserves, location of meristematic tissues, tiller dynamics and pattern of leaf senescence (Parsons et al., 1983; Bircham and

Hodgson, 1984). A key morphological adaptation to defoliation is the location of shoot meristems below the soil surface (Hyder, 1973). Stoloniferous and rhizomatous species are therefore better adapted to defoliation than most tufted species (Rodel, 1971).

Hacker and Minson (1981) discussed the variation in IVOMD between plant parts. They reported the mean IVOMD of leaf lamina of grasses to range from 46 to 82%. Leaf IVOMD was found to vary up to 40 percentage units within a species. Differences in leaf IVOMD increases between the top and bottom portions of the canopy with maturity. The IVOMD of the leaf fraction declines with maturity and senescence. Stem IVOMD was found to range from 5% to more than 85% and varied as much as 26 units within a single grass stem. Stobbs (1973) studied the distribution of nitrogen and IVOMD by vertical layers in leaf and stem fractions of two tropical grasses. Nitrogen content of herbage decreased with maturity and decreased from top layer to the basal layer. The leaf fraction contained a higher percentage of nitrogen than the stem fraction. In vitro digestibility decreased with maturity and also decreased from top to basal layers within each sward.

Persistence. The high cost of pasture establishment and renovation renders persistence a desirable feature in a pasture species. Characteristics associated with

persistence include tolerance to grazing, drought, cold, and disease, and regeneration from stolons, rhizomes or seed.

Mislevy et al. (1988) studied the effect of grazing frequency on the persistence of Cynodon spp. at AREC Ona. Ground cover of weeds was 25 percentage units less on plots of Callie 35-3 bermudagrass and Florico stargrass than Ona stargrass. In another study, Mislevy et al. (1981) reported that Florico and Florona stargrasses averaged 3 and 6% weed ground cover, respectively, compared to 12% for Ona stargrass. The relatively high persistence of Florico and Florona stargrass has been associated with allelopathy or superior competitiveness (Mislevy et al., 1981).

Mislevy (1987) evaluated the effect of 5-, 10-, 15-, 20- and 25-cm stubble heights and 0-, 15-, 30-, 45- and 60-cm plant heights above the stubble on persistence of Florico, Ona, and Florona stargrasses. Grazing all three grasses rotationally at 45-cm plant height above the stubble to a 25-cm stubble height, resulted in 8, 3, and 1.5% weed ground cover, respectively. Percent weed-ground cover increased to 23, 21 and 3%, respectively, at 30-cm plant height above stubble and 5-cm stubble height. Reducing stubble height from 25 to 5 cm resulted in an increased weed cover of 21, 44, and 1%, on plots of Florico, Ona, and Florona stargrasses respectively.

In a 4-yr clipping study, Kalmbacher et al. (1987) noted that Florona and Florico stargrasses spread faster and

had less weed cover than Ona stargrass at Immokalee. However, Cynodon entries were generally less persistent than Hemarthria entries, when N was applied at an annual rate of 56 kg ha^{-1} under a 35-d harvest schedule. Stolon length and density are important criteria for competitiveness. Mislevy et al. (1982) reported longer and denser stolons for Florico and Florona stargrasses than for Pangola digitgrass under cool conditions. Rodriguez and Silva (1975) found that a better stand of Florico stargrass was maintained with high (15 to 20 cm) than low (2.5 to 7.5 cm) grazing stubble. They also indicated that with a low grazing stubble the stand of Florico stargrass increased with length of grazing interval, but with high grazing stubble, grazing interval had little effect. Velez-Santiago and Arroyo-Aguilu (1983) studied the effect of 30-, 45-, and 60-d clipping interval on weed infestation of Florico stargrass pastures. Plots were less infested at the 60- and 45-d clipping interval than at the 30-d interval.

Forage Quality

Forage quality is best defined in terms of animal performance (Moore, 1980). Animal performance is a function of voluntary intake, rate and extent of digestion, and the efficiency of energy use (Marten, 1985). Forage quality depends upon the physical and chemical composition of the forage and their interactions with animal factors (Van

Soest, 1982; Marten, 1985; Mott and Moore, 1985). Composition of the forage is related to soil type, climate, forage species, and management practices (Van Soest, 1982; Mislevy, 1987).

Tropical grasses are lower in quality compared to temperate grasses (Minson, 1980). Characteristics of tropical grasses, which relate to lower quality, compared to temperate species include: lower bulk density of leaf, lower leaf:stem ratio, lower crude protein (CP) and digestibility, higher indigestible cell wall constituents, and rapid rate of maturation (Minson, 1980; Mott, 1981; Norton, 1982; Morris, 1984).

Nutritive Value. Voluntary intake (VI) of forages is primarily controlled by the rate and extent of digestion in the rumen. However, in tropical forages CP of 60 to 80 g kg^{-1} dry matter (DM) or lower may reduce VI below that limited by rumen distention (Minson, 1980). Concentration of CP and IVOMD are therefore important determinants of forage quality and have been shown to be correlated to VI ($r = 0.65$ to 0.99), in some tropical grasses (Arroyo-Aguilu et al., 1975).

Concentration of CP and IVOMD in forage species generally decline with advancing maturity (Arroyo-Aguilu et al., 1975). The effect of grazing frequency on IVOMD and CP of Florico stargrass and Callie 35-3 bermudagrass, was studied by Mislevy et al. (1988). Average IVOMD for May-to-June-

harvested forage of Florico stargrass was 580 g kg^{-1} OM, irrespective of grazing frequency. However, IVOMD of Callie 35-3 bermudagrass decreased linearly with a delay in grazing frequency. In both grass entries, IVOMD of September-harvested forage declined by 32 g kg^{-1} OM for each week delay in grazing frequency from 2 to 7 wk. Concentration of CP for May-June and September-harvested forages followed a similar trend as IVOMD.

Mislevy et al. (1982) found small differences in IVOMD of June-, August- and September-harvested Florico and Florona stargrasses. However, IVOMD of Florico was 60 to 80 g kg^{-1} OM higher than Florona stargrass. The IVOMD of both grass entries decreased more than 50 g kg^{-1} OM, when grazing frequency was decreased from 2 to 7 wk. Mean CP concentration of Florico and Florona stargrasses in June, August and September ranged from 120 to 140 g kg^{-1} DM when fertilized with 45 kg ha^{-1} N. Several studies in Puerto Rico with Florico stargrass (Sotomayor-Rios et al., 1976; Caro-Costas et al., 1976, 1981; Mendez-Cruz et al., 1988) support the general conclusion that concentration of CP and IVOMD decrease with advancing maturity.

In a digestion trial, Brown et al. (1988) evaluated the nutritional value of Florico stargrass and Callie 35-3 bermudagrass. Florico had the lowest concentration of acid detergent lignin (ADL) and the highest IVOMD, while Callie 35-3 bermudagrass was highest in ADL and lowest in IVOMD.

The general decline in concentration of CP and IVOMD of tropical grasses, with advancing maturity, has been partly attributed to increasing cell wall contents (CWC, Van Soest, 1982). Arroyo-Aguilu et al. (1975) evaluated the relationship between chemical composition and IVOMD of Florico stargrass in Puerto Rico. Florico stargrass was superior in IVOMD to guineagrass (Panicum maximum Jacq.) and Pangola digitgrass. They noted that CWC, especially lignin and cellulose in Florico stargrass, increased with advancing maturity. Cellulose and silica were negatively correlated to IVOMD ($r = -0.97$ to -0.98). Lignin was the dominant factor determining digestibility ($r = -0.97$).

Intake is the most important factor affecting the quality of tropical grasses (Minson, 1980). Intake is controlled by metabolic, distention, and behavioral mechanisms (Hodgson, 1985b). In forage-fed ruminants, the distention and behavioral mechanisms exert important effects on intake under confined and grazing conditions, respectively (Hodgson, 1985b). The distention mechanism relates intake directly to rumen fill and inversely to retention time (Van Soest, 1982). Rate and extent of digestion of cell wall constituents and rate of passage have been suggested as the most important factors influencing forage intake (Poppi et al., 1981; Van Soest, 1982).

Many factors are known to affect VI of ruminants (Cordova et al., 1978; Meijs, 1981; Minson, 1982; Leaver,

1982). The most important factors that are of sward-origin include: maturity, species, digestibility, chemical composition, herbage mass, and sward canopy structure (Meijs, 1981; Leaver, 1982). In Puerto Rico, Yazman et al. (1977) found that VI of 45-d old Florico stargrass hay was 1.5 percentage (expressed as percentage of body weight) units lower than that of 30-d old hay. Mendez-Cruz et al. (1988) reported that VI of five tropical grasses, including Florico stargrass, was independent of stage of maturity. In another study, VI of 30-, 45- and 60-d maturity Florico stargrass hays did not differ (Gutierrez-Vargas et al., 1978). Caro-Costas and Vincente-Chandler (1981), found no difference in dry matter disappearance when Florico stargrass pastures with equal stocking rate were grazed at 14-, 21- and 28-d intervals.

Research has shown that substantial variation in intake occurs between species. Intake of 30-d maturity Florico stargrass hay was greater than Pangola digitgrass (Roman-Garcia et al., 1979). The VI of 45-d maturity Florico stargrass hay was 2.0% higher than Coastal bermudagrass. Brown et al. (1988) found no difference in VI of 42-d maturity hays of Florico and Florona stargrass. Intake of Florico was 2.7% greater than Ona stargrass and Callie 35-3 had the lowest VI.

Relationship between dry matter digestibility and VI is highly variable (Minson, 1980). Rates of digestion and

passage of CWC are more important determinants of VI than digestibility (Van Soest, 1982). In tropical forages, CP of 60 to 80 g kg^{-1} DM or lower depresses intake (Minson, 1980). The VI of leaf fractions is generally higher than stem fractions of similar digestibility (Poppi et al., 1981), due to shorter rumen retention time of leaf fractions.

Animal Performance. Florico stargrass (called star in Puerto Rico) is the most widely used pasture grass for beef and dairy cattle feeding in Puerto Rico (Vincente-Chandler et al., 1974). Caro-Costas and Vincente-Chandler (1981) found no difference in ADG and gain ha^{-1} for Florico stargrass pastures grazed at 14-, 21-, and 28-d intervals for 3 yr at an annual fertilization rate of 336-49-186 kg ha^{-1} of N-P-K in the humid mountain region of Puerto Rico. Daily gain and gain ha^{-1} ranged from 0.51 to 0.54 kg and 1000 to 1242 kg yr^{-1}, respectively.

Effect of three levels of annual fertilization (269-40-216, 470-69-260 and 672-99-371 kg ha^{-1} of N-P-K) on animal performance from Florico stargrass pastures was evaluated over a 2-yr period by Caro-Costas et al. (1976). Liveweight gain ha^{-1} responded to fertilization up to 672-99-371 kg of N-P-K. The ADG ranged between 0.61 to 0.65 kg and was not affected by variation in rate of fertilization.

Caro-Costas et al. (1976) compared animal gains on Florico stargrass, Pangola digitgrass, and Congograss (Brachiaria ruzizensis) over a 2-yr period at Orocovis,

Puerto Rico. The ADG and gain ha^{-1} on Florico stargrass were 12 and 14%, respectively, higher than on Congograss. In another study, Caro-Costas et al. (1972) reported ADG and gain ha^{-1} of 0.60 kg and 1512 kg, respectively, on Florico stargrass pastures, which were 10 and 18% higher, respectively, than gains on Pangola digitgrass pastures. Roman-Garcia et al. (1979) reported gains of 0.69 and 0.64 kg d^{-1} for Holstein calves fed 30- and 45-d maturity Florico hays, respectively, over a period of 160 d. Caro-Costas et al. (1979) noted that cows on Florico stargrass pastures produced 16% more milk than those on guineagrass. The reported range of ADG (0.45 to 0.72 kg d^{-1}) on Florico in the humid region of Puerto Rico is relatively greater than gains on commonly used warm-season grasses in Florida.

A review of the literature indicates the highest ADG on warm-season forages in Florida range from 0.33 to 1.1 kg (Dunavin, 1970; Hodges et al., 1976; Pitman et al., 1984; Sollenberger et al., 1987). Hodges et al. (1976) in a 5-yr grazing trial obtained highest warm-season ADG of 0.41 and 0.36, respectively, on 'McCaleb' stargrass (C. aethiopicus Clayton and Harlan) and Pangola digitgrass. Cattle gain ha^{-1} was highest on Pangola digitgrass (365 kg), while Argentine bahiagrass was the lowest producer of liveweight gain. In another study, warm-season ADG ranged from 0.28 to 0.46 kg for five grasses evaluated between 1 and 5 yr at

AREC Ona (Hodges et al., 1979). The 5-yr ADG and gain ha^{-1} for Ona stargrass were 0.46 kg and 546 kg, respectively.

Adjei et al. (1980) studied the effect of three stocking rates on animal performance when grazing three stargrass cultivars (McCaleb, Ona, and experimental UF-5 C. aethiopicus Clayton and Harlan), Transvala digitgrass, and Pensacola bahiagrass over a 2-yr period at Ona. The ADG (at 10 cattle ha^{-1}) in the first year of the study on stargrass, digitgrass, and bahiagrass averaged 0.35, 0.28 and 0.22 kg, respectively, while gain ha^{-1} averaged 580, 461 and 396 kg, respectively. Two-year ADG and gain ha^{-1} for the stargrasses (at 7.5 cattle ha^{-1}) ranged from 0.36 to 0.56 kg and 453 to 686 kg, respectively.

Pitman et al. (1984) evaluated steer performance on four tropical grasses at Ona, over a 3-yr period. Warm-season (mid-March to October) ADG on Ona stargrass (0.51 kg), Callie bermudagrass (0.48 kg), and Bigalta limpograss (0.51 kg) did not differ. Total gain ha^{-1} differed, averaging 607, 513, and 532 kg for Ona, Callie, and Bigalta, respectively. The ADG was correlated to IVOMD ($r = 0.42$ to 0.58).

Brown et al. (1988) compared steer gains on Ona stargrass and Florico over a 84-d period at the, AREC Ona. The ADG of steers (0.59 and 0.47 kg) and gain ha^{-1} (594 and 513 kg) were greater on Florico pastures than on Ona stargrass. Animal performance on three bermudagrasses (Callie, Tifton

72-81 and 72-84) and Pensacola bahiagrass were compared over a 3-yr period at Jay (Bertrand and Dunavin, 1985). The bermudagrasses produced greater ADG (0.42 to 0.49 vs. 0.37 kg) and gain ha^{-1} (451 to 469 vs. 351 kg) than Pensacola bahiagrass.

In the first year of a continuous grazing trial at Gainesville, Florida, 'Floralta' limpograss produced ADG of 0.35 kg compared to 0.33 kg for Pensacola bahiagrass (Quesenberry et al., 1984). Sollenberger et al. (1988) studied animal performance on continuously stocked Pensacola bahiagrass and Floralta limpograss pastures over a 2-yr period. Daily gains did not differ between grasses in either year of study and averaged 0.33 and 0.38 kg on bahiagrass and limpograss, respectively.

Gieger (1978) reported total liveweight gain ha^{-1} of 720 kg and 494 kg for animals grazing Floralta limpograss and Pensacola bahiagrass, respectively. It was noted that the "summer slump" period for Floralta corresponded with the period when CP concentration of hand-plucked forage samples fell below 70 kg^{-1} DM. Over the season, neither CP concentration nor IVOMD was correlated with ADG.

Animals grazing perennial grass and grass-legume pastures generally lose weight from August through September in Florida (Prates et al., 1974; Pitman et al., 1984; Rusland et al., 1988). This phenomenon has been termed the "summer slump." Prates et al. (1974) reported steer gains on

bahiagrass of 1.0 kg d^{-1} in May, which decreased to -0.52 kg d^{-1} in September, increasing to 0.15 kg d^{-1} in October.

Comparatively high animal gains and absence of "summer slump" has been reported for animals grazing `Mott' dwarf elephantgrass (Pennisetum purpureum (L.) Schum) in Gainesville (Sollenberger et al., 1988). Mott (1984) reported ADG on the same species of 0.90 kg from June through December. Gain averaged 1.1 kg d^{-1} from August through September. The same author reported ADG of 0.91 kg on Mott compared to 0.25 kg on Pensacola bahiagrass over a 2-yr period. Gain ha^{-1} for dwarf elephantgrass averaged 492 compared to 236 kg on Pensacola bahiagrass.

Canopy Structure and Ingestive Behavior

Herbage intake is a major determinant of animal output (Minson, 1980). In grazed pastures, structural characteristics of the sward, through their effect on ingestive behavior, determine intake and consequently, animal performance (Chacon et al., 1978).

Grazing time (T), rate of biting (R), and bite weight (W) are the major components of ingestive behavior (Hodgson, 1985a). Attempts have been made (Chacon et al.,1976; Forbes and Coleman, 1985) to estimate forage intake (I) of the grazing ruminant from the expression

$$I = T \times R \times W.$$

The components of ingestive behavior interact. Bite weight has the dominant influence on I, with R and T as compensatory variates (Hodgson, 1981). The influence of sward canopy characteristics on W and R is briefly reviewed in this section.

Bite weight is the component of ingestive behavior that is most sensitive to sward variation (Hodgson, 1981) and the major determinant of I (Chacon and Stobbs, 1976; Hodgson, 1985a; Moore and Sollenberger, 1986). With declining herbage mass, grazing animals generally compensate for low W by increasing T and R (Stobbs, 1973, 1974; Kanyama-Phiri and Conrad, 1986).

Bite weight varies with species composition of the sward (Stobbs, 1973; Ludlow et al., 1982). Cattle grazing pure grass swards had larger W than cattle on grass-legume swards (Brown et al., 1987b). Stobbs (1973) found W of dairy cattle on tropical pastures varied from 0.05 g to 0.60 g OM per bite. A positive linear relationship between W and sward height has been reported in cattle and sheep grazing temperate and tropical swards (Allden and Whittaker, 1970; Chacon and Stobbs, 1976; Hodgson, 1981). However, a positive relation between W and sward height is by no means universal. Stobbs (1973) observed a negative relationship between W and sward height on tall tropical grasses with low leaf density in the surface horizon. Data presented by Forbes and Coleman (1985) tend to support the negative

relationship. The depth of the leaf canopy and density of herbage within the leafy layer are critical in determining W (Moore and Sollenberger, 1986). Barthram (1980) found that sheep seldom penetrate horizons containing pseudostems or dead material.

A positive linear relationship between green herbage mass in the canopy and W have been reported (Hodgson and Jamieson, 1981; Chacon et al., 1978; Butler et al., 1987). In Hemarthria altissima-Aeschynomene americana pastures, W of cattle was not affected by legume bulk density, nor percentage of legume in the upper layer, but by percent green herbage (Moore and Sollenberger, 1986). Stobbs (1973) reported that leaf bulk density combined with high leaf to stem ratio exerted a major influence on W. Both Arnold (1981) and Minson (1981) reported an animal preference for green leafy tissue. Minson (1981) suggested reporting forage leaf and stem yields separately, and Stobbs (1973) estimated that pasture yields below 1000 kg ha^{-1} result in W of less than 300 mg OM.

A high proportion of dead material in the sward canopy depresses W (Chacon et al., 1978). Herbage intake and animal performance are, therefore, more closely related to green leaf mass than herbage allowance or herbage mass (Chacon et al., 1978; Butler et al., 1987). A negative relationship between non-green herbage and liveweight gain was reported by Ebersohn et al. (1985).

Leaver (1986) found that W of sheep declined as the season progressed due to decreasing herbage. Brown et al. (1987b) found that W of cattle declined in a quadratic manner from pre- (d-1) to post- (d-14) grazing periods. Bite weight on alfalfa (Medicago sativa L.) declined linearly for each hour increment in grazing time (Dougherty et al., 1987).

Biting rates declined linearly over the course of the grazing period (Brown et al., 1987b; Dougherty et al., 1987), probably due to decreasing herbage mass. In a 14-d grazing period, Brown et al. (1987a) found that R declined quadratically from pre- (d-1) to post-graze (d-14) periods. However, some studies have shown R to increase with declining herbage mass and herbage allowance (Chacon and Stobbs, 1976; Jamieson and Hodgson, 1979; Dougherty et al., 1987), possibly due to greater manipulatory jaw movement. Moore and Sollenberger (1986) found a negative relationship between total herbage mass and R ($r = -0.54$). Scarnecchia et al. (1985) reported that as standing crop decreased from 474 to 170 kg DM ha^{-1} R by Angus heifers increased from 56 to 64 bites min^{-1}.

Allden and Whittaker (1970) reported both linear and quadratic relationships between R and tiller height for sheep on ryegrass. Hodgson (1981) found no deviation from linearity between rate of intake and sward height in either calves or lambs set-stocked on ryegrass swards. In another

trial Hodgson (1981) reported reduced R with declining sward height for calves under strip-grazing management. Hodgson and Jamieson (1981) attributed low R found in lactating cows to tall swards.

Kanyama-Phiri and Conrad (1986) reported a negative linear relationship between R and pasture height. Rate of biting for cows and heifers decreased by 1.9 and 3.1 bites min^{-1} for each 2.5 cm increase in sward height.

A negative correlation between T and sward height or herbage mass has been reported in many studies (Allden and Whittaker, 1970; Chacon and Stobbs, 1976; Jamieson and Hodgson, 1979). Allden and Whittaker (1970) found T of sheep increased with a decline in herbage mass below 1000 kg ha^{-1}. Chacon and Stobbs (1976) found poor correlation between T and sward characteristics when a tropical grass sward was grazed down over a period of 2 wk. Jamieson and Hodgson (1979) reported a negative relationship between T and green herbage mass for both calves and lambs.

Carbohydrate Reserves and Regrowth

The importance of plant food reserves in pasture management has been well documented. Proper management has been related to maintenance of maximum reserves above a 'critical level' (Cook, 1966). This part of the review examines the role of total nonstructural carbohydrates (TNC) in plant regrowth following defoliation.

Present evidence indicates that leaf area, root reserves, and nutrient uptake contribute to regrowth (Younger, 1972), but this varies with species and environment. In grasses, glucose, fructose, sucrose, maltose, starch, and fructosans are the major nonstructural carbohydrate reserves (Smith, 1973). Grasses of tropical and subtropical origin accumulate starch; grasses of temperate origin accumulate fructosans (Ojima and Isawa, 1968; Smith, 1973). Substances other than carbohydrates, such as proteins and fats, are also believed to be involved in regrowth of grasses (Sullivan and Sprague, 1943; Davidson and Milthorpe, 1965). Nonstructural carbohydrates may be stored temporarily in all plant parts. Most studies, however, indicate that the major storage organs are root and stem bases, including stolons, corms and rhizomes (Baker and Garwood, 1961; Navarro-Chavira and McKersie, 1983).

Total nonstructural carbohydrates are often considered the primary source of energy for regrowth (Smith, 1973; Deregibus et al., 1982). Studies using labeled carbon-14 have provided direct evidence of the role of TNC in the regrowth of many plants (Smith and Marten, 1970; Bokhari, 1977). However, in several species, little if any mobilization of TNC from roots following defoliation has been reported (Marshall and Sagar, 1965; Davidson and Milthorpe, 1966). Relating the contribution of TNC to regrowth has therefore been difficult, possibly due to concurrent

photosynthesis or tiller meristem limitations (May, 1960; Richards and Caldwell, 1985; Forwood et al., 1988; Anderson et al., 1989).

Many factors, such as temperature and solar radiation, soil moisture, soil nutrients and season, influence TNC levels and subsequently forage regrowth after defoliation (Smith, 1973; Forwood et al., 1988; Anderson et al., 1989). For many tropical grasses, TNC accumulation occurs during the cool or dry season (Ferraris, 1978; Mislevy et al., 1988). The TNC drain is most intense during the summer or growing season, due to high temperatures and growth rates.

Reserves are apparently utilized for regrowth for a short time (2 to 7 d) following defoliation (Davidson and Milthorpe, 1966; Richards and Caldwell, 1985). Following the initial period, plant regrowth depends on other factors, such as leaf area and nutrient uptake. Defoliation of grasses reduces root growth, TNC, and leaf area (Younger, 1972; White, 1973). As a rule, the severity of these effects depends on the intensity, frequency, and season of defoliation.

Adjei (1988a) studied the effect of low, medium, and high stocking rates on TNC of three stargrass cultivars (UF-5, McCaleb, and Ona), Transvala digitgrass, and Pensacola bahiagrass under rotational grazing (2-wk grazing, 4-wk rest). The TNC concentration was monitored weekly in root-crown (5 cm root and 2.5 cm stubble), low-stubble (2.5

to 10.0 cm), and upper-stubble (> 10 cm) regions. The TNC concentration depended on species. In stargrasses, concentration of TNC in the root-crown was higher than that in the stubble. The TNC concentration was greater in the stubble than in the roots of digitgrass and higher in the rhizomes than roots of bahiagrass. Stubble and root TNC concentration in all species showed a marked quadratic response to grazing. The TNC in root-crowns and lower stubble of stargrasses was linearly reduced by increased stocking rate. In another study, Adjei et al. (1988b) found no definite relationship between grazing frequency and crown TNC concentration of eight limpograss cultivars. Percent average crown TNC decreased from 55 for the first season to 42 g kg^{-1} DM at the beginning of the third season of grazing.

Mislevy et al. (1988) monitored TNC concentrations of seven stargrass cultivars including Florico and Florona under 2-, 4-, 5-, and 7-wk grazing frequencies in four periods (April to May, May to June, September, and November to December). The TNC concentration in the crown region of all grasses for the April to May (dry) period was about double the average of the other three periods for each grazing frequency.

Animal Response to Stocking Rate and Grazing Pressure

Stocking rate (SR) is the number of animals of a specific class per unit of land area or its reciprocal over a

period of time (Hodgson, 1979). Grazing pressure (GP) was proposed by Mott (1960) as the criterion for assessing the similarity of stocking rate experiments. Hodgson (1979) defines GP as the number of animals of a specified class per unit weight of herbage and herbage allowance as the weight of herbage per unit of animal weight.

Various researchers have proposed mathematical relationships between SR, ADG, and gain ha^{-1}. Mott (1960) proposed the exponential model which predicts an optimum SR for ADG and a maximum gain ha^{-1} at a slightly higher SR. At a SR below the optimum, the model predicts little change in ADG with changes in SR, while above optimum, ADG declines rapidly with increasing SR. His model was of the form

$$Y_a = k - ab^x$$

where Y_a = ADG, x = stocking rate, k, a, and b are constants.

Petersen et al. (1965) proposed a model in which ADG remained constant as SR increased to an optimum (critical) level. In this model, gain ha^{-1} increased linearly to the critical SR, and decreased linearly with further increase in SR. Jones and Sandland (1974) proposed a linear model of the form

$$Y_a = a - bx.$$

Jones (1981) noted that ADG is a non-linear function of SR. He divided the generalized ADG and SR curve into regions where

1. Increased SR is accompanied by increased ADG and gain ha^{-1}.
2. Average daily gain is constant with increasing SR, but gain ha^{-1} increases linearly.
3. Increase in SR results in a decline in ADG.

He indicated that in the region where pasture potential is limiting, ADG generally declines linearly with increases in stocking rate (when animal potential is not limiting).

Average daily gains of grazing animals generally decrease as grazing pressure increases. Roth et al. (1986) studied the effect of high, medium high, medium, and low grazing pressures on ADG, OM intake and diet quality of four classes of cattle grazing coastal bermudagrass pastures. The ADG of all classes of cattle was curvilinearly related to grazing pressure. Neutral detergent fiber (NDF) and IVOMD content of steer diets were 2 and 12 percentage units higher at the low than high grazing pressure, while OM intake of steers was 11% higher at the low than high grazing pressure.

Mott (1980) concluded that at forage availability of 1200 to 1600 kg ha^{-1} or from 4 to 6 kg of available forage 100-kg^{-1} liveweight d^{-1}, animal output reaches a maximum. Duble et al. (1971) suggested that forage quality was the

predominant factor affecting animal performance at levels of standing forage beyond certain minimum standing forage levels. These minimum standing forage levels were shown by Duble et al (1971) to differ with forage digestibility and were determined to be 500, 1,000 and 1,250 kg ha^{-1} for forage digestibilities greater than 60 g kg^{-1}, 50 to 60 g kg^{-1} and less than 50 g kg^{-1}, respectively. Adjei et al. (1980) noted that ADG of steers grazing stargrass pastures was a curvilinear function of grazing pressure, with an optimum grazing pressure of 6 to 8 kg available forage DM 100-kg^{-1} liveweight d^{-1}.

CHAPTER III
FORAGE PRODUCTION, QUALITY, CARBOHYDRATE TRENDS AND STEER PERFORMANCE FOR CALLIE 35-3 BERMUDAGRASS, AND FLORICO AND FLORONA STARGRASSES UNDER GRAZING

Introduction

Forage production and quality are important forage evaluation criteria (Mott and Moore, 1970; Mochrie et al., 1981). Concentration of total nonstructural carbohydrates (TNC) in root-crown areas of grasses may affect regrowth, and influence choice of grazing management. (Bokhari, 1977; Deregibus et al., 1982). Thus, experiments to quantify these responses are needed for potential cultivars.

'Florico' and 'Florona' stargrasses (Cynodon nlemfuensis Vanderyst var. nlemfuensis) and Callie hybrid 35-3, an experimental bermudagrass (C. dactylon (L.) Pers.), have superior forage production, persistence, crude protein (CP) concentration, and in vitro organic matter disappearance (IVOMD) when compared with 'Ona' stargrass (C. nlemfuensis Vanderyst var. nlemfuensis), a commercial cultivar (Mislevy et al., 1980; Mislevy, 1988; Kalmbacher et al., 1987). Florico and Florona were released to Florida producers in 1988.

Carrying capacity and animal performance of most perennial grasses adapted to south Florida have been reported by several researchers (Hodges et al., 1976, 1979; Adjei et al., 1980; Pitman et al., 1984). In a preliminary study, Brown et al. (1988) found no difference in organic matter intake and in vivo digestibility for Ona, Florico, and Florona stargrasses. However, average daily gain (ADG) of steers on Florico pastures was 11% greater than those on Ona stargrass.

Little information is available on forage production, CP concentration, IVOMD, seasonal TNC trends, and animal performance on Callie 35-3 bermudagrass and Florico and Florona stargrasses. Accordingly, this study was conducted to compare

1. Herbage accumulation, herbage nutritive value and seasonal trends in TNC concentration of root-crown of the three grasses, and
2. Daily gain, carrying capacity, herbage disappearance, and utilization of forage-on-offer for Callie 35-3 bermudagrass and Florico and Florona stargrass pastures under rotational grazing.

Materials and Methods

Site

The experiment was conducted during the growing seasons (May through December) of 1986, 1987, and 1988, at the

University of Florida's Ona Agricultural Research and Education Center (AREC, 27° 26' N, 81° 55'W). Rainfall and temperature data during the experimental period are presented in Table 3-1 and Table 3-2. Soil at the experimental site was a Pomona fine sand (sandy siliceous, hyperthermic Ultic Haplaquod), with an average pH of 6.5 maintained over the study period.

Pasture and Animal Management

Four 0.5-ha pastures each of Callie 35-3, Florico, and Florona were established in 1980 and supported grazing along with several hay crops before the present experiment began. Experimental design was a randomized complete block design with four pasture replications in 1986 and 1987, and two in 1988. Phosphorus and K were applied at mean annual rates of 23 and 90 kg ha^{-1}, with 20 kg ha^{-1} of a micronutrient mix (F-503) that supplied 0.3 kg B, 0.3 kg Cu, 1.8 kg Fe, 0.75 kg Mn, 0.02 kg Mo, and 0.7 kg Zn ha^{-1} in December or January each winter. Nitrogen was applied in four equal applications March, May, July, and September at an annual rate of 224 kg ha^{-1}. Pastures were burned in March of each year to remove stubble remaining from the previous year.

Each replication was divided into three 0.17-ha equal size paddocks. Paddocks were grazed in a rotation of 2-wk grazing followed by a 4-wk rest to give a grazing cycle length of 6-wk (Table 3-3). A modified "put and take" grazing management system was used. Two yearling Brahman

Table 3-1. Rainfall data for 1986, 1987, and 1988, and a 36-yr average recorded at the AREC*, Ona during the grazing period.

Month	1986	1987	1988	36-yr avg.
	----------	mm	----------	
May	71	71	87	59
June	297	78	219	101
July	215	192	219	212
Aug.	137	173	324	223
Sept.	129	72	217	209
Oct.	158	130	49	81
Nov.	25	86	43	47
Dec.	127	11	23	47
Total	1159	813	1181	979

* AREC = Agricultural Research and Education Center.

Table 3-2. Mean maximum (MAX) and minimum (MIN) temperatures in 1986, 1987, and 1988 at the AREC*, Ona during the grazing period.

	Temperature					
	1986		1987		1988	
Month	MAX	MIN	MAX	MIN	MAX	MIN
	---------- °C ----------					
May	31	17	31	18	30	15
June	32	21	33	21	32	20
July	33	22	33	21	33	21
Aug.	32	22	33	22	33	23
Sept.	32	22	33	21	33	23
Oct.	30	19	28	16	28	17
Nov.	29	19	26	16	27	16
Dec.	24	14	24	11	24	11
Mean	30	20	30	18	30	18

* AREC = Agricultural Research and Education Center.

Table 3-3. Grazing cycle dates in 1986, 1987, and 1988.

Grazing cycle number	Date	
	Starting	Ending
	1986	
1	2 May	13 June
2	14 June	25 July
3	26 July	5 Sept.
4	6 Sept.	17 Oct.
5	18 Oct.	24 Nov.
	1987	
1	21 May	2 July
2	3 July	13 Aug.
3	14 Aug.	24 Sept.
4	25 Sept.	5 Nov.
5	6 Nov.	17 Dec.
	1988	
1	25 May	6 July
2	9 July	17 Aug.
3	20 Aug.	28 Sept.
4	29 Sept.	9 Nov.
5	10 Nov.	21 Dec.

crossbred steers averaging 240, 245 and 260 kg, were assigned as "tester" animals per 0.5-ha pasture each year and up to two grazers were added or removed depending on forage availability. Grazers generally were added or removed at the end of a cycle.

Full weights of steers were taken on two consecutive days at the beginning and end of grazing each year. Unshrunk weights were taken at 6-wk intervals throughout the grazing season. Steers had free access to mineralized salt (Table A-1) and water. Weight data of testers were used to calculate ADG. Carrying capacity (CC) was calculated using both tester and grazer animals (Mott and Lucas, 1952). Gain ha^{-1} was calculated as the product of ADG and CC, adjusted for the weight of the average tester.

Pasture Sampling

Herbage mass (HM, instantaneous measure of total weight of herbage per unit area of ground) at the start (pregraze) and end (postgraze) of grazing in each paddock was estimated from 3-m^2 plots randomly selected and harvested to a stubble height of 75 mm. Subsamples (0.20 kg) were dried at 60°C for 48 h and reweighed in order to calculate dry HM ha^{-1}. Dried subsamples were ground for CP (Gallaher et al., 1975; Hambleton, 1977) and IVOMD (Moore and Mott, 1974) analyses.

Two paddocks of each grass were sampled weekly for root-crown (25 mm fibrous roots and 50 mm stubble) TNC determination using a mechanical core sampler measuring 100

mm in diameter. Crown samples were washed free of soil, heated at 100°C for 1 h to inactivate respiratory enzymes, after which they were dried at 60°C for 48 h. Samples were weighed after drying in 1987, but not in 1986, ground to pass a 1-mm screen, and frozen until TNC analysis.

Persistence of grass entries was determined by estimating percentage ground cover of common bermudagrass (C. dactylon L.). However no statistical difference existed between grass entries, therefore this response variable was omitted from the paper.

Laboratory Analysis

Subsets of 150 samples from each of the pregraze, postgraze, and root-crown sample types representing all grasses and cycles were selected for each year. Pregraze and postgraze subsets were analyzed for N and IVOMD as described above. Root-crown samples were analyzed for TNC (Nelson, 1944; Somogyi, 1945; Smith, 1981). Crude protein concentration, IVOMD, and TNC for the remainder of the samples were predicted by near infrared reflectance spectroscopy (Norris et al., 1976; Brown et al., 1987a). Total nonstructural carbohydrate 'pool' (TNCP) in the root-crown was estimated as the product of the TNC concentration and the root-crown biomass.

Calculations and Assumptions

Because of the length of the grazing period, growth during grazing was accounted for in all calculations of

herbage accumulation (the change in herbage mass between successive measurements and summed over time when necessary) using formulae proposed by Campbell (1966a). Pasture growth rate (GR), herbage accumulated per grazing cycle (HA), forage-on-offer per grazing cycle (FOF), and herbage accumulated per grazing season (THA) were estimated based on the assumption that GR was linear during a given rest and grazing period as follows

1. $GR = B_i - A_{(i-1)} / RD$,
2. $HA = B_i - A_{(i-1)} + [(B_i - A_{(i-1)} / RD) \times GD]$,
3. $THA = HA_{(c1 + \ldots + c5)}$
4. $FOF = B_i + [(B_i - A_{(i-1)} / RD) \times GD]$,

where

B_i = herbage mass (HM) kg ha^{-1} before grazing period i;

$A_{(i-1)}$ = HM kg ha^{-1} after grazing period i-1;

RD = days of rest;

GD = days of grazing.

$HA_{(c1 + \ldots + c5)}$ = sum of HA kg ha^{-1} for all cycles.

Herbage allowance (HAL, the weight of herbage per unit animal weight) per cycle was estimated by dividing herbage accumulated per day (FOF/42 d) by the 100 kg liveweight of steers carried for the cycle. Herbage disappearance (the mass of herbage per unit area removed by grazing animals) per cycle was estimated as the difference between FOF and postgraze HM. Utilization (UT, efficiency of grazing) of herbage per cycle was calculated as the ratio of herbage

disappearance to FOF multiplied by 100. Since laboratory analyses for CP and IVOMD were run on whole-canopy (75 mm stubble) subsamples, CP concentration and IVOMD in the grazed horizon (100 mm) were estimated by the difference method (Frame, 1981) using observed values for pregraze and postgraze HM.

Statistical Analysis

Data were analyzed as a split-plot in time experiment with grass entry as the main plot and cycle as the subplot (Petersen, 1985), using the General Linear Model (GLM) and Analysis of Variance (ANOVA) procedures (SAS, 1982). Year was included in the model as the subplot when seasonal responses were analyzed. When grass x cycle interactions were significant, within cycle ANOVA was used to check for treatment differences. Model sum of squares were partitioned to test for linear and quadratic effects of sampling weeks on TNC. All mean separation was done by Duncan's multiple range test and protected LSD at the 0.05 level of significance.

Results and Discussion

Herbage Accumulation

Total herbage accumulation differed among grasses in 1986 and 1987 (Table 3-4). Florona had the highest THA in 1986 (20.1 Mg ha^{-1}) and 1987 (16.6 Mg ha^{-1}), followed by Florico (18.5 and 14.6 Mg ha^{-1}), with Callie 35-3 yielding

Table 3-4. Seasonal herbage accumulation from rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986 and 1987.

	Year	
Grass	1986	1987
	--------Mg ha^{-1}-------	
Callie 35-3	15.8 c†	9.4 c
Florico	18.5 b	14.6 b
Florona	20.1 a	16.6 a
SE‡	2.3	2.1
2-yr avg.	18.1 a	13.5 b

† Means within years followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

‡ SE = standard error of the mean.

the lowest THA in both years (15.8 and 9.4 Mg ha^{-1}). These values were higher than those reported under 4-wk mob-grazing (Mislevy et al., 1988), probably due to the fact that in the mob-grazing study regrowth was measured from clipped stubble with very little or no residual leaf area. The THA for all grasses in 1986 was higher than in 1987; difference in rainfall may be partly accountable.

Herbage accumulated per cycle tended to be lower on Callie 35-3 compared to Florico and Florona (Table 3-5) in 1986 and 1987. The HA was highest for cycles 2 and 3, and lowest for cycle 5 in 1986. In 1987, HA was highest in cycles 2, 3, and 4, with the lowest HA in cycles 1 and 5. Herbage accumulation tends to be lowest for cycle 5 partly because of the dry conditions and shorter days.

Grass x cycle interactions ($P < 0.03$) existed in 1986 and 1987 for FOF (Table 3-6). In 1986, Florona had the highest FOF in cycles 1 and 3. The FOF for Florico was lower than Florona and Callie 35-3 during cycle 2. Callie 35-3 had the lowest FOF during cycle 5, probably because this cold tolerant grass was going into winter dormancy. Forage-on-offer for Florico and Florona increased from cycle 1 to 3, while FOF for Callie 35-3 increased from cycle 1 to 2 and then dropped until the end of the season. In 1987, Florona had the highest FOF in cycles 1, 2, and 4 compared with Callie 35-3 and Florico. The FOF of Callie 35-3 did

Table 3-5. Mean herbage accumulation per cycle from rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986 and 1987.

Grazing cycle no.	Grass: Callie 35-3	Florico	Florona	Mean	SE†
	----------Mg ha^{-1}----------				
			1986		
1	3.2	4.1	4.6	3.9 b‡	0.4
2	4.6	5.0	4.7	4.7 a	0.2
3	3.8	3.8	5.6	4.4 ab	0.4
4	2.7	3.7	3.2	3.2 c	0.3
5	1.5	2.0	2.0	1.8 d	0.3
Mean	3.2 b§	3.7 a	4.0 a		
SE	0.4	0.5	0.4		
			1987		
1	1.1	1.7	1.8	1.6 b	0.3
2	3.1	3.6	4.3	3.6 a	0.2
3	2.3	3.6	3.7	3.2 a	0.5
4	2.5	3.7	5.2	3.8 a	0.6
5	0.4	2.0	1.6	1.3 b	0.2
Mean	1.9 b	2.9 a	3.3 a		
SE	0.3	0.4	0.4		

† SE = standard error of the mean.

‡ Cycle means within years followed by the same letter(s) are not different ($P > 0.05$), according to Duncan's Multiple Range Test.

§ Grass means within years followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

Table 3-6. Mean forage-on-offer on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986 and 1987.

Grazing cycle no.	Grass: Callie 35-3	Florico	Florona	SE†
	---------- Mg ha^{-1} ----------			
	1986			
1	4.5 b‡	4.7 b	6.4 a	0.3
2	6.5 a	5.6 b	6.6 a	0.2
3	5.7 b	6.5 b	8.2 a	0.5
4	4.4 b	5.9 a	4.6 b	0.4
5	2.9 b	4.6 a	4.9 a	0.4
$LSD_{0.05}$§	0.6	0.5	0.7	
SE	0.3	0.4	0.6	
	1987			
1	3.1 b	3.2 b	4.1 a	0.2
2	5.5 b	5.1 b	6.7 a	0.4
3	4.2 b	5.3 a	6.0 a	0.5
4	3.2 c	5.1 b	6.6 a	0.3
5	1.2 b	3.3 a	2.6 a	0.2
$LSD_{0.05}$	0.4	0.8	0.5	
SE	0.2	0.4	0.5	

† SE = standard error of the mean.

‡ Means in a row within years followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range test.

§ LSD for comparison between cycles for each grass.

not differ from Florico in cycles 1 and 2; however, Callie 35-3 had the lowest FOF in cycles 3, 4, and 5.

Grass x cycle interactions were obtained for postgraze herbage mass (POHM) in 1986 and 1987 (Table 3-7). In 1986, POHM was greater on Callie 35-3 and Florona than on Florico in cycle 1. No differences were detected between grass entries in POHM for cycle 2. Postgraze herbage mass generally greater on Florona pastures than on Callie 35-3 for cycles 3, 4, and 5. Pastures of Florico had the lowest POHM for cycle 1 in 1987. There were no differences in POHM between grass entries for cycles 2 and 4. The POHM was greater on pastures of Florico and Florona stargrasses than Callie 35-3 for cycles 3 and 5, partly because stocking rate was slightly heavy on Callie 35-3 which resulted in grazing to a lower stubble along with less growth towards fall. The lower POHM is reflected in the higher utilization of FOF for Callie 35-3. The FOF differed between cycles because animal numbers were adjusted mainly at the beginning and end of the season.

Nutritive Value

No grass x cycle interaction was detected for CP and IVOMD; neither were there differences in CP among grass entries in 1986 and 1987 (Table 3-8). Mislevy et al. (1982) found no difference in CP for June and September harvests (4- to 5-wk regrowth) of Florico and Florona stargrass under mob-grazing. Kalmbacher et al. (1987) found no difference

Table 3-7. Mean postgraze herbage mass on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986 and 1987.

Grazing cycle no.	Grass: Callie 35-3	Florico	Florona	SE†
	---------- Mg ha^{-1}----------			
	1986			
1	1.3 a‡	0.6 b	1.8 a	0.1
2	2.1 a	2.7 a	2.2 a	0.2
3	1.7 b	2.2 a	3.3 a	0.2
4	1.4 b	2.7 a	3.0 a	0.4
5	1.1 b	1.9 ab	2.1 a	
$LSD_{0.05}$§	0.5	0.4	0.4	
SE	0.2	0.2	0.3	
	1987			
1	1.9 ab	1.5 b	2.4 a	0.1
2	1.9 a	1.7 a	2.2 a	0.1
3	0.8 b	1.4 a	1.6 a	0.2
4	1.3 a	1.1 a	0.9 a	0.1
5	0.3 b	1.3 a	0.9 a	0.2
$LSD_{0.05}$	0.4	0.3	0.05	
SE	0.3	0.2	0.04	

† Standard error of the mean.

‡ Means in a row within years followed by the same letter(s), are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ LSD for comparison between cycles for each grass.

Table 3-8. Mean crude protein (CP) and in vitro organic matter disappearance (IVOMD) in herbage accumulated for Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986, and 1987.

Year	Grass			
	Callie 35-3	Florico	Florona	SE†
	-------- CP (g kg^{-1}) -------			
1986	79 a‡	74 a	74 a	3.8
1987	92 a	101 a	97 a	4.4
	------ IVOMD (g kg^{-1}) -----			
1986	555 ab	566 a	533 b	6.0
1987	526 b	571 a	520 b	4.5

† Standard error of the mean.

‡ Means in a row followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

in CP concentration of summer harvested (5-wk regrowth) Florico and Florona stargrasses. Mean CP for Callie 35-3, Florico, and Florona ranged from 79 to 92, 74 to 101, and 74 to 97 g kg^{-1}, respectively.

The IVOMD of Florico was greater than Florona in 1986 and 1987 (Table 3-8); however, IVOMD for Callie 35-3 and Florona did not differ in either year. Mislevy et al. (1982) reported differences in IVOMD of June harvested (4-wk regrowth) Florico (600 g kg^{-1}) and Florona (510 g kg^{-1}) however, the IVOMD of September harvested forage in the same study did not differ. Kalmbacher et al. (1987) found no difference in IVOMD of summer harvested (5-wk regrowth) Florico and Florona. Brown et al. (1988) found digestibility of Florico to be 3% higher than Florona.

In 1986, CP was greater for cycle 2; there were no differences between cycles 1, 3, 4, and 5 (Table 3-9). Concentration of CP was higher in cycles 4 and 5 than for 1, 2, and 3 in 1987 probably due to less rainfall and drier edaphic conditions during the last two cycles. Mean IVOMD was higher in cycle 1 in each year and lowest in cycles 4 and 5. In 1986, IVOMD in cycles 2, 3, and 4 did not differ. The IVOMD in cycle 2 differed from cycles 3, 4, and 5 in 1987.

Crown TNC Trends

There were significant grass x cycle interactions for TNC in 1986 and 1987 (Table 3-10). In 1986, TNC concentration in the root-crown region of all grass entries declined

Table 3-9. Calculated crude protein (CP) concentration and in vitro organic matter disappearance (IVOMD) in herbage accumulated per cycle and averaged over grasses for 1986 and 1987.

Grazing cycle no.	1986 CP	1986 IVOMD	1987 CP	1987 IVOMD
	g kg^{-1}			
1	66 b†	611 a	100 b	601 a
2	104 a	572 b	101 b	577 b
3	69 b	552 b	102 b	522 c
4	71 b	527 c	126 a	513 c
5	70 b	511 c	112 a	504 c
SE‡	5.1	7.1	6.7	9.2

† Means in a column within years followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

‡ Standard error of the mean.

Table 3-10. Response of total nonstructural carbohydrates concentration (TNC) and TNC pool (TNCP) in the root-crown area of Callie 35-3 bermudagrass, Florico and Florona stargrass pastures under 2-wk grazing and 4-wk rest over five grazing cycles in 1986 and 1987.

Week in cycle	Year 1986 TNC	1987 TNC	1987 TNCP†
	----- g kg^{-1} ------		- g -
Callie 35-3			
1	66	59	11
2	58	57	12
3	68	54	11
4	68	58	12
5	72	60	13
6	74	60	12
F test‡			
Cycle	Q‡*	L* Q*	NS
Seasonal	L** Q*	L**	L*
Florico			
1	57	59	15
2	54	55	16
3	54	54	15
4	60	51	16
5	68	52	18
6	67	52	16
F test‡			
Cycle	L** Q**	L* Q*	NS
Seasonal	L* Q*	L**	L**
Florona			
1	57	52	12
2	47	49	14
3	52	46	14
4	58	52	13
5	61	49	14
6	60	50	13
F test‡			
Cycle	Q**	L** Q**	NS
Seasonal	L** Q*	Q**	L*

† TNCP = TNC concentration x biomass of root-crown.

‡ Linear (L) or quadratic (Q) effects.

* and ** = P < 0.05 and 0.01, respectively.

(linear and quadratic effects) with weeks over the season. The decline in TNC may be partly attributed to utilization of stored reserves in replacement of leaf and stem tissues removed by grazing. Mislevy et al. (1988) reported greater TNC concentration in the root-crown area of Callie 35-3 and Florico in April to May sampling of winter (December to May) stockpiled forage than in November and December. The linear decline in TNC over the season may be due to the high summer temperatures which are associated with rapid growth rates, production of new tillers and flower heads. In 1987 the response of TNC was linear for Callie 35-3 and Florico, and quadratic for Florona. Differences between species in TNC response to grazing have been reported (Adjei et al., 1988). The TNCP response was linear for Callie 35-3 and Florico.

Within a grazing cycle TNC concentration generally declined (linear and quadratic) from the first through the third week. Adjei et al. (1988) reported both linear and quadratic decline in TNC for Ona stargrass within a grazing cycle.

Herbage Allowance

Grass x cycle interactions ($P < 0.01$) were detected in 1986 and 1987 for herbage allowance (HAL) (Table 3-11). In 1986, HAL on Florona was higher than on Callie 35-3 and Florico for cycle 1. The HAL on Callie 35-3 and Florona was greater than on Florico in cycle 2. Herbage allowance on Callie 35-3 pastures was lower than Florico and Florona for

Table 3-11. Grass x cycle interaction for herbage allowance on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986 and 1987.

Grazing cycle no.	Grass: Callie 35-3	Florico	Florona	SE†
	--kg DM 100 kg^{-1} liveweight d^{-1}--			
	1986			
1	6.1 b‡	6.3 b	8.4 a	0.4
2	8.4 a	6.7 b	7.9 a	0.9
3	6.7 b	7.5 b	9.2 a	0.7
4	5.1 b	6.4 a	7.1 a	1.5
5	3.2 b	4.8 a	5.2 a	0.7
$LSD_{0.05}$§	0.07	0.8	0.7	
SE	1.4	1.2	1.1	
	1987			
1	3.8 a	3.8 a	4.8 a	0.6
2	5.1 b	5.1 b	6.8 a	0.4
3	4.2 b	5.0 ab	5.8 a	1.0
4	3.0 c	4.5 b	6.0 a	0.4
5	1.1 b	2.9 a	2.3 a	0.7
$LSD_{0.05}$	0.8	0.6	0.8	
SE	1.0	0.7	0.5	

† Standard error of the mean.

‡ Means in a row within years followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ LSD for comparison between cycles for each grass.

cycles 4 and 5 in both years. In 1987, HAL did not differ among grass entries for cycle 1. However, HAL on Florona was greater than Callie 35-3 and Florico during cycle 2, with Callie 35-3 having the lowest HAL for cycle 3. Herbage allowance ranged from 1.1 to 8.4, 2.9 to 7.5, and 2.3 to 9.2 kg DM $100kg^{-1}$ liveweight d^{-1} on pastures of Callie 35-3, Florico, and Florona. Adjei et al. (1980) reported that ADG of steers grazing stargrass pastures reached a maximum when herbage allowance was 6 to 8 kg DM $100\text{-}kg^{-1}$ liveweight d^{-1}.

The HAL differed between grass entries partly because of differences in grazing pressure. Callie 35-3 was generally grazed to a lower stubble height than the stargrasses due to lower FOF. Moreover, having more cold tolerance, Callie 35-3 goes into winter dormancy earlier in the season resulting in reduced forage production. Animal numbers were adjusted only towards the end of the season based on visual appraisal, hence the differences in HAL between cycles. Generally, the lower HAL on Callie 35-3 may be partly accountable for the lower ADG compared to Florico and Florona.

Herbage Disappearance

There were grass x cycle interactions ($P < 0.01$) in both 1986 and 1987 for HD. In 1986, no difference was detected for HD between grass entries for cycles 1 and 4, however Callie 35-3 had the highest HD in cycle 2, while Florico had the lowest (Table 3-12). Florona had the highest HD in

Table 3-12. Herbage disappearance on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986 and 1987.

Grazing cycle no.	Grass: Callie 35-3	Florico	Florona	SE†
	--kg DM 100 kg^{-1} liveweight d^{-1}--			
		1986		
1	4.7 a‡	5.4 a	5.9 a	0.4
2	5.7 a	3.6 c	4.7 b	0.3
3	4.7 b	4.9 ab	5.5 a	0.3
4	3.3 a	3.5 a	3.9 a	0.2
5	2.0 b	2.8 ab	3.0 a	0.2
$LSD_{0.05}$§	0.7	0.6	0.6	
SE	0.3	0.3	0.4	
		1987		
1	1.4 b	2.0 ab	2.2 a	0.3
2	3.3 b	3.5 b	4.5 a	0.1
3	3.4 b	3.7 ab	4.5 a	0.1
4	1.7 c	3.5 b	5.1 a	0.4
5	0.6 b	1.7 a	1.5 a	0.2
$LSD_{0.05}$	0.4	0.3	0.5	
SE	0.2	0.4	0.4	

† Standard error of the mean.

‡ Means in a row within years followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ LSD for comparison between cycles for each grass.

cycles 3 and 5 compared to Callie 35-3 and Florico. In 1987, HD on Florona pastures was higher than on Callie 35-3 in all cycles. The HD on Florico pastures did not differ from Callie 35-3 for cycles 1, 2, and 3. The lower HD and HAL in cycles 4 and 5 in both years may be attributed to the lower HA as the season advanced.

Utilization

Utilization of FOF was higher on Florico compared with Callie 35-3 and Florona for cycle 1 in 1986 (Table 3-13); however, UT was lower on Florico in cycle 2. Utilization of FOF tended to be greater on Callie 35-3 than on Florico and Florona for cycles 4 and 5. In 1987, UT of FOF did not differ among grass entries in cycles 1 and 2, however UT of FOF was higher on Callie 35-3 for cycle 3 compared to Florico and Florona. Utilization was greater on Callie 35-3 and Florona than on Florico during cycles 4 and 5. Generally, UT of FOF tended to be higher on Callie 35-3 partly because of the smaller FOF and consequently lower HA compared to Florico and Florona stargrasses. Adjei et al. (1980) obtained a mean utilization of 75% for three stargrasses stocked at 7.5 steer ha^{-1}. Utilization tended to be generally greater for cycles 2, 3, and 4, probably due to excessive trampling of herbage below the clipping stubble height.

Table 3-13. Utilization by steers of available forage on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986 and 1987.

Grazing cycle no.	Grass: Callie 35-3	Florico	Florona	SE†
	---------- (%) ----------			
	1986			
1	74 b‡	86 a	71 b	8
2	67 a	52 b	60 a	6
3	70 a	66 ab	59 a	5
4	68 a	55 b	54 b	9
5	62 a	58 b	57 b	6
$LSD_{0.05}$§	12	9	11	
SE	4	7	10	
	1987			
1	46 a	53 a	42 a	7
2	59 a	66 a	66 a	6
3	81 a	72 b	73 b	11
4	86 a	78 b	85 a	9
5	66 a	56 b	64 a	5
$LSD_{0.05}$	11	10	13	
SE	7	8	10	

† Standard error of the mean.

‡ Means in a row within years followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ LSD for comparison between cycles for each grass.

Carrying Capacity

No year x grass interaction was found for CC. Mean CC (3-yr average) on Florona (1573 d ha^{-1}) and Florico (1472 d ha^{-1}) were greater than on Callie 35-3 (1332 d ha^{-1}). The CC on Florona was greater than on Florico and Callie 35-3 in 1986. No difference was detected between grass entries for CC in 1988 (Table 3-14). Carrying capacity is a measure of forage quantity under the put and take management system (Mott and Lucas, 1952). Thus, the greater CC on Florona and Florico compared to Callie 35-3 was a direct consequence of the higher HA. Perhaps the lower CC on Callie 35-3 could be partially attributed to less rapid regrowth following grazing because less leaf area remained. Since the stargrasses have higher residual HM and stubble after grazing, their leaf area was also higher than Callie 35-3. Hodges et al. (1976) reported CC of 1473 d ha^{-1} for Ona stargrass. Pitman et al. (1984) reported CC of 969 and 829 d ha^{-1} for Ona stargrass and Callie bermudagrass (C. dactylon var. aridus), respectively.

Average Daily Gain

Steer ADG differed among grass entries in 1986 and 1987, with the ADG on Florico being higher than Florona and Callie 35-3 (Table 3-15). Pitman et al. (1984) reported significant correlations between ADG and IVOMD of FOF for Sarasota (C. dactylon var. coursii (camus) Harlan et de Wet) and Ona stargrasses and Callie bermudagrass. Thus, the

Table 3-14. Mean seasonal carrying capacity on rotationally-grazed Callie 35-3 bermudagrass, Florico, and Florona stargrass pastures in 1986, 1987, and 1988.

Year	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- d ha^{-1}----------			
1986	1489 b‡	1480 b	1639 a	42
1987	1269 b	1499 a	1511 a	59
1988	1239 a	1417 a	1573 a	57
3-yr avg.	1332 b	1472 a	1573 a	

† Standard error of the mean.

‡ Means in a row followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

Table 3-15. Mean seasonal average daily gain (ADG) of steers on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986, 1987 and 1988.

Year	Grass			
	Callie 35-3	Florico	Florona	SE†
	ADG (kg)			
1986	0.30 c‡	0.48 a	0.37 b	0.04
1987	0.48 b	0.62 a	0.49 b	0.02
1988	0.35 a	0.43 a	0.41 a	0.03
3-yr avg.	0.38 b	0.51 a	0.42 b	

† SE = Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different ($P > 0.05$), according to Duncan's Multiple Range Test.

greater ADG on Florico compared to Florona could be partly attributed to many factors including, higher IVOMD, while the difference in ADG between Callie 35-3 and Florico may be due to lower HAL and HD.

Daily gains obtained in the present study are equal to or slightly higher than those reported for other stargrass studies in south Florida. Hodges et al. (1976, 1979) reported ADG of 0.41 kg and 0.46 for McCaleb (C. aethiopicus Clayton et Harlan) and Ona stargrasses respectively when stocked at 2.5 steers ha^{-1}. Adjei et al. (1980) reported a range of 0.36 to 0.56 kg for three stargrasses at a stocking rate of 7.5 steer ha^{-1}, while Pitman et al. (1984) reported warm season ADG of 0.51 for Ona stargrass stocked at 2.5 steers ha^{-1}. Brown et al. (1988) reported daily gains of 0.59 and 0.47 kg for Florico and Ona stargrasses stocked at 2.5 steers ha^{-1}.

Gain ha^{-1}

Beef gain ha^{-1} on Florico (602 to 929 kg) and Florona (583 to 750 kg) did not differ from each other over the 3-yr study (Table 3-16). There was no year x grass interaction. The lowest gain ha^{-1}, ranging from 434 to 604 kg was obtained on pastures of Callie 35-3.

Gain ha^{-1} is a product of ADG and CC (Mott and Lucas, 1952). Therefore, the greater gain ha^{-1} on Florico and Florona compared to Callie 35-3 may be partly attributed to the greater ADG and CC. The lower gain ha^{-1} on Callie 35-3

Table 3-16. Mean beef gain on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrass pastures in 1986, 1987 and 1988.

Year	Grass			
	Callie 35-3	Florico	Florona	SE†
	--------	kg ha^{-1}	--------	
1986	446 b‡	710 a	583 ab	28
1987	604 b	929 a	750 ab	37
1988	434 b	602 a	633 a	43
3-yr avg.	495 b	751 a	655 a	

† Standard error of the mean.

‡ Means in a row followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

bermudagrass compared to Florico and Florona stargrasses could be attributed to a combination of factors such as lower HA and HD. Brown et al. (1988) reported lower dry matter intake and higher acid detergent lignin for Callie 35-3 compared to Florico and Florona stargrasses. Gain ha^{-1} obtained in this study compares favorably with the literature for other stargrasses. Hodges et al. (1979) reported gains of 546 kg for Ona stargrass, Adjei et al. (1980) reported a range of 453 to 513 kg ha^{-1} for McCaleb, Ona, and UF-5 (C. aethiopicus Clayton et Harlan) stargrass, while Pitman et al. (1984) reported gain ha^{-1} of 619 kg for Ona stargrass. Bertrand and Dunavin (1985) reported gain of 451 kg ha^{-1} on Callie bermudagrass. Brown et al. (1988) reported gains of 594 and 513 kg ha^{-1} for Florico and Ona stargrasses, respectively.

Perhaps the major contributing factor to the lower animal performance on Callie 35-3 could be the inherent cold adaptation which might have been responsible for carbohydrate storage early in the season, and consequently less forage growth after October. Field notes indicate that Callie 35-3 started growth earlier in the season than Florico with greater FOF between May and June. Furthermore, disparity in steer daily gains between Callie 35-3 and Florico became pronounced as the season advanced, suggesting that Callie 35-3 could occupy a niche in the forage-livestock system in south Florida earlier in the growing season and on

pasture sites that are located in cold areas. This observation agrees with the findings of Pitman et al. (1984) who found that Callie bermudagrass (one of the parents of Callie 35-3) started growth earlier in the season than Sarasota stargrass. This is an area that needs further research.

CHAPTER IV
SWARD CANOPY COMPOSITION AND INGESTIVE BEHAVIOR OF STEERS GRAZING CALLIE 35-3 BERMUDAGRASS AND FLORICO AND FLORONA STARGRASSES

Introduction

Feed intake is the major determinant of animal output (Minson, 1980). Herbage intake under grazing is a function of time spent grazing, bite weight, and biting rate (Hodgson, 1985a), which are generally influenced by canopy characteristics (Stobbs, 1973; Chacon et al., 1978). Canopy structure and composition of temperate (Jamieson and Hodgson, 1979) and tropical (Chacon and Stobbs, 1976) forages could undoubtedly influence herbage intake and consequently animal performance under grazing.

Callie 35-3 bermudagrass (Cynodon dactylon (L.) Pers.) and Florico and Florona stargrasses (C. nlemfuensis Vanderyst var. nlemfuensis) are highly productive tropical grasses with potential for use both as conserved and grazed forage in south Florida (Mislevy et al., 1988, 1989a, 1989b). Organic matter digestibility and intake of Florico and Florona stargrass hays by steers were similar to Ona stargrass (C. nlemfuensis Vanderyst var. nlemfuensis), a commercial cultivar (Brown et al., 1988). However, average daily gains (ADG) of steers on Florico were higher than on

Ona stargrass (Brown et al., 1988), and Florona stargrass and Callie 35-3 bermudagrass (Chapter III).

A knowledge of canopy composition and ingestive behavior of steers grazing Callie 35-3 bermudagrass, Florico, and Florona stargrasses may help explain differences in animal performance and in making appropriate grazing management recommendations. The objectives of this study were to compare

1. Herbage mass (HM), in vitro organic matter disappearance (IVOMD), and crude protein (CP) concentration of top, middle, and bottom horizontal canopy layers, and botanical composition of each layer of rotationally-grazed Callie 35-3 bermudagrass and Florico and Florona stargrass pastures on d 1, 7, and 14 of a 2-wk grazing cycle.
2. In vitro organic matter disappearance and CP concentration of the diet selected by steers grazing Callie 35-3 bermudagrass and Florico and Florona stargrass pastures on d 1, 7, and 14 of a 2-wk grazing period.
3. Bite weight, biting rate, and intake rate of steers grazing Callie 35-3 bermudagrass and Florico and Florona stargrass pastures on d 1, 7, and 14 of a 2-wk grazing period.

Materials and Methods

Site

The study was conducted at the University of Florida's Ona Agricultural Research and Education Center (27° 26′ N, 81° 55′) on a Pomona fine sand (sandy silicious, hyperthermic Ultic Haplaquod), from May through December 1987. It was part of a larger grazing trial conducted over five grazing cycles (Table 4-1), in which 0.5-ha pastures of Callie 35-3 bermudagrass and Florico and Florona stargrasses were divided into three equal units, and were grazed rotationally with 2-wk grazing and 4-wk regrowth. The experimental variables imposed in the grazing trial and the responses of forage yield, nutritive value, and animal performance were reported in Chapter III.

Canopy Measurements

Two 0.2-ha replicated pastures of Callie 35-3, Florico and Florona were sampled by cutting four random 0.5 m^2 quadrats on d 1 (pregraze), d 7 (midgraze), and d 14 (postgraze) of a 2-wk grazing period. A plastic pipe frame (Moore and Sollenberger, 1986) was used to define the quadrats. Herbage within quadrats was cut in 100 mm stratified horizontal layers from the top of the canopy using electric hand-held grass shears. Fresh samples from each stratum were weighed and divided into two subsamples, 1) separated subsample, 2) unseparated subsample. The hand-separated subsample was divided into green leaf, green stem, dead and

Table 4-1. Sampling dates for ingestive behavior and canopy characteristics study.

Grazing cycle no.‡	Sampling day†		
	1	7	14
	Dates		
1	20 May	27 May	2 June
2	3 July	10 July	17 July
3	14 Aug.	21 Aug.	28 Aug.
4	25 Sept.	2 Oct.	9 Oct.
5	6 Nov.	13 Nov.	20 Nov.

† Day in a 2-wk grazing period.

‡ 6-wk grazing cycle.

weed components. Green leaf was defined as leaf blades which were more than 50% green, while blades with less than 50% green tissue were regarded as dead. The 'stem' fraction was comprised of culms, stolons plus inflorescence, and leaf sheaths. All samples were dried at 60°C for 48 h. The unseparated subsample plus the sum of the leaf, stem and dead components in a layer was estimated to obtain whole layer herbage mass. Subsamples were composited across layers within each replication and ground to pass a 1-mm screen to determine CP concentration and IVOMD. The sward canopy was divided into top (> 300 mm), middle (200 to 300 mm) and bottom (100 to 200 mm) layers. Herbage mass, CP, and IVOMD were estimated for the top layer by calculating weighted means of actual values for each 100-mm horizontal layer above 300 mm.

Ingestive Behavior Measurements

Bite weight, biting rate, and rate of herbage intake were estimated from data taken from two mature (5- to 7-yr), non-resident, esophageally fistulated Brahman crossbred steers averaging 400 to 500 kg in liveweight. Steers grazed bahiagrass (Paspalum notatum Fluegge) pastures in holding areas until 24 h before sampling for ingestive behavior, which occurred on the day following sampling of pasture for canopy characteristics. Steers were then fasted overnight (13 to 16 h) and allowed to graze for 20 to 30 min with resident steers.

Sampling was conducted between 0700 h and 1000 h. Two samples were taken from each animal giving a total of four observations per pasture. Visual observation and mechanical hand tally counters were used to count actual bites during the observation period. A bite was defined as sound of forage being severed (Moore and Sollenberger, 1986). Esophageal extrusa samples were collected in screen-bottom canvas bags, then weighed, and hand mixed. Subsamples (200 to 360 g) were dried at 60° C for 48 h, and then ground to pass a 1 mm-screen for CP concentration and IVOMD.

Bites per minute were estimated by dividing total number of recorded bites by number of minutes required to make those bites. Weight of esophageal samples was divided by the total number of grazing bites to obtain bite weight. Rate of intake was estimated by multiplying g bite^{-1} by bites min^{-1}.

Statistical Analysis

The experimental design was a randomized complete block with two replications. Data were analyzed as a split-split-plot in time experiment (Petersen, 1985). Grass entry, sampling day or layer, and grazing cycle were mainplot, subplot, and sub-subplot, respectively. Ingestive behavior data were analyzed as a split-split-plot in time experiment with grass entry, sampling day and cycle as mainplot, subplot, and sub-subplot, respectively. The General Linear Models (GLM) and Analysis of Variance (ANOVA) procedures of

SAS (1982) were used. Model sums of squares were partitioned to test for linear and quadratic effects of sampling day. All means separation was done by Duncan's Multiple Range Test and protected LSD at the 0.05 level of significance. The correlation procedure (SAS, 1982) was used to obtain simple correlation coefficients between sward canopy and ingestive behavior response variables for each entry.

Analysis of canopy data was approached in two ways

1. In the whole-canopy approach, layer was not included in the model. The objective of this approach was to characterize the whole canopy and monitor changes in the canopy on d 1, 7 and 14 of grazing.
2. In the period approach, sampling day was not included in the model. The major objective of this approach was to monitor changes in the top, middle, and bottom layers of the canopy on either d 1, 7 or 14 of grazing. The pregraze (d 1) canopy was chosen because all layers were represented.

Laboratory Analysis

Three hundred subsets from the canopy and extrusa samples were selected and analyzed for concentrations of CP (Gallaher et al., 1975; Hambleton, 1977) and IVOMD (Moore and Mott, 1974). Crude protein concentration and IVOMD for

the remainder of the samples were predicted using near-infrared reflectance spectroscopy (Norris et al., 1976).

Results and Discussion

Canopy Characteristics

Whole Canopy. Total HM of the whole-canopy declined linearly for all grass entries from d 1 to d 14 of grazing (Table 4-2). Mean total HM of the whole-canopy was greater for Florona than for Callie 35-3 on d 1. Callie 35-3 had the lowest HM on d 7 and 14 when compared with Florona. The lower whole canopy HM on Callie 35-3 bermudagrass compared with Florona is consistent with the results in Chapter 3, and may be attributed to lower forage-on-offer (FOF), and postgraze HM resulting from greater grazing pressures and the tendency of Callie 35-3 to go into winter dormancy earlier than the stargrasses.

Leaf HM declined linearly from d 1 to d 14 of grazing on all grass entries probably due to consumption and trampling by steers. Brown et al. (1987b) reported a decline in bulk density of Ona stargrass from pre- to postgrazing period. Leaf mass on d 1 did not differ between grass entries. On d 7, however, leaf mass was lower on Callie 35-3 bermudagrass when compared with Florona, probably due to easy accessibility of leaves in the canopy of Callie 35-3 bermudagrass to steers. Leaf mass in the whole-canopy (200 mm stubble) was greater on d 14 for Florico than for Callie

Table 4-2. Mean whole-canopy, leaf, and stem herbage mass of Callie 35-3 bermudagrass, Florico and Florona stargrass sward canopies on d 1, 7, and 14 of a 2-wk grazing period.

Grass	Sampling day 1	7	14	P† L	P† Q
	------- kg ha^{-1} ----------				
		Whole-canopy			
Callie 35-3	581 b‡	237 b	123 b	0.01	0.16
Florico	846 ab	461 ab	341 a	0.01	0.47
Florona	1066 a	593 a	297 a	0.01	0.51
SE§	101	94	72		
		Leaf			
Callie 35-3	271 a	92 b	29 b	0.01	0.44
Florico	412 a	188 ab	133 a	0.04	0.23
Florona	416 a	240 a	100 ab	0.01	0.43
SE	54	46	48		
		Stem			
Callie 35-3	247 b	145 a	99 b	0.01	0.44
Florico	434 ab	273 a	233 a	0.04	0.23
Florona	650 a	253 a	184 ab	0.01	0.26
SE	34	45	33		

† Probability for sampling day effect, linear (L) or quadratic (Q).

‡ Means in a column within sampling day followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ Standard error of the mean.

35-3, suggesting that steers on Florico could be selecting a diet of higher quality than those on Callie 35-3.

There was a linear decline in stem HM from d 1 to d 14 of grazing (Table 4-2) for all grass entries, due to consumption by cattle. On d 1, stem HM of Florona was greater than Callie 35-3, which may partly explain the lower IVOMD of Florona stargrass when compared to Callie 35-3. Grass entries did not differ in stem HM on d 7. Callie 35-3 had the lowest stem mass on d 14 possibly due to lower FOF which might have resulted in steers consuming more stems on Callie 35-3 compared with the stargrasses.

Leaf composition of the whole-canopy decreased linearly from d 1 to 14 of grazing for all grass entries (Table 4-3). This agrees with the findings of Brown et al. (1987b), and may be a possible cause for the decline in bite weight, biting rate and consequently intake rate from d 1 to 14. Sward canopies of Florico had greater percentage leaf composition than Florona on d 1. No difference was detected in percentage composition of leaf on d 7. Callie 35-3 had the lowest leaf composition on d 14 of sampling, which reflects the lower FOF for Callie 35-3 compared to Florona, and partly explains the lower bite weight on Callie 35-3.

Stem composition increased in the canopies of all grass entries from d 1 to 14 (Table 4-3). The increase was linear on Callie 35-3, and both linear and quadratic on Florico and Florona. This difference in response may be due to the

Table 4-3. Component composition of Callie 35-3 bermudagrass, Florico and Florona stargrass pastures on d 1, 7, and 14 of a 2-wk grazing period.

Grass	Sampling day 1	7	14	P† L	P† Q
	---------- % ----------				
		Leaf			
Callie 35-3	47 ab‡	39 a	22 b	0.01	0.03
Florico	49 a	41 a	39 a	0.01	0.36
Florona	39 b	40 a	34 a	0.01	0.84
SE§	4	2	4		
		Stem			
Callie 35-3	43 b	52 a	74 a	0.01	0.44
Florico	51 ab	58 a	60 b	0.01	0.05
Florona	61 a	59 a	62 b	0.01	0.02
SE	2	4	7		

† Probability for sampling day effect, linear (L) or quadratic (Q).

‡ Means in a column within periods followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

§ Standard error of the mean.

lower leaf mass in the canopies of Callie 35-3 compared to Florico and Florona. The increase in stem with the corresponding decrease in leaf component from d 1 to 14 of grazing suggests that leaf was selected against stem. Percentage of stem in the sward canopies was generally similar for grass entries on d 1 and 7. Callie 35-3 had the highest stem percentage on d 14, since most leaf mass was consumed by steers near the end of grazing period.

There were grass x cycle interactions ($P < 0.02$) for IVOMD of whole-canopy, and the leaf and stem fractions in the canopy (Table 4-4). Whole-canopy IVOMD of Callie 35-3 was greater than Florona in cycle 1. Florico had the highest IVOMD in cycles 2 and 4. Grass entries did not differ in whole-layer IVOMD for cycle 3. Callie 35-3 had higher IVOMD in cycles 1 and 5 compared to cycles 2, 3, and 4. The IVOMD of Florona was higher in cycle 1 than in cycles 2 and 4. Callie 35-3 and Florico leaves were generally higher in IVOMD than Florona (Table 4-4). The IVOMD of Callie 35-3 leaves tended to be higher in cycles 4 and 5 than in cycles 2 and 3, possibly due to cooler temperatures and drier soil conditions during this time of the season resulting in decreased growth rate and consequently reduced rate of cell wall accumulation. The IVOMD of Florico and Florona leaves showed erratic trends with cycle, possibly due to production of new tillers at different periods during the grazing season. The IVOMD of stem did not differ between grass

Table 4-4. Mean in vitro organic matter disappearance for whole-canopy, leaf, and stem components of Callie 35-3 bermudagrass, Florico, and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Grass		
	Callie 35-3	Florico	Florona
	---------- g kg^{-1} ----------		
	Whole canopy		
1	580 a† A‡	566 ab A	525 b A
2	484 b B	577 a A	433 b B
3	485 a B	505 a B	480 a AB
4	453 b B	519 a A	460 b B
5	552 a A	532 ab A	473 b AB
	Leaf		
1	596 a BC	577 a C	490 b B
2	584 a C	601 a ABC	532 b AB
3	563 b C	593 a BC	565 b A
4	629 a AB	620 a AB	582 b A
5	646 a A	640 a A	534 b AB
	Stem		
1	547 a A	530 a A	515 a A
2	468 a B	512 a A	465 a A
3	460 a B	466 a A	485 a A
4	455 a B	458 a A	480 a A
5	510 a AB	520 a A	510 a A

† Means in row followed by the same lowercase letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test (DMRT).

‡ Means in a column followed by the same uppercase letter(s) are not different ($P > 0.05$) according to DMRT.

entries regardless of cycle. Stems of Callie 35-3 had higher IVOMD in cycle 1 than in cycles 2, 3 and 4. Florico and Florona stems did not differ in IVOMD with cycle.

Sampling day x cycle interacted ($P < 0.03$) for HM of the whole-canopy (Table 4-5). Whole-canopy generally declined from d 1 to 14 within a cycle, this may partly explain the observed decline in bite weight and biting rate within cycles from d 1 to 14. Herbage mass on d 1 was generally greater for cycles 3 and 4 and least in cycle 5. The decline in whole canopy HM as the season advanced may be associated with shorter days, drier soil conditions and cooler temperatures, resulting in reduced growth rate.

Crude protein concentration of the stem fraction of the canopy declined linearly with sampling day in cycle 1, 3 and 5 and quadratically in cycles 2, 3, 4 and 5 from d 1 to 14 (Table 4-6). Crude protein concentration for d 1 was greater in cycle 1 and least in cycles 2, 3 and 4. Crude protein concentrations for d 7 and 14 were greater in cycle 5 and lower in cycles 3 and 1, respectively. The decline in CP concentration within a cycle may be attributed to increase lignification associated with maturation, and a decline in leaf to stem ratio. Differences in CP concentration between cycles may partly be due to the onset of flower heads, since the stem fraction in the present study included flower heads.

Table 4-5. Mean whole-canopy herbage mass of Callie 35-3 bermudagrass, Florico and Florona stargrass pastures on d 1, 7, and 14 of a 2-wk grazing period over five grazing cycles.

Grazing cycle no.	Sampling day			P†	
	1	7	14	L	Q
	------- kg ha^{-1} ----------				
1	663 bc‡	616 ab	231 a	0.01	0.15
2	823 b	280 bc	353 a	0.01	0.03
3	1200 a	739 a	374 a	0.01	0.73
4	877 ab	316 bc	224 a	0.01	0.16
5	411 c	209 c	95 a	0.02	0.70
SE§	121	106	94		

† Probability for sampling day effects, linear (L) or quadratic (Q).

‡ Means in a column within sampling day followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

§ Standard error of the mean.

Table 4-6. Mean crude protein concentration of stem in Callie 35-3 bermudagrass, Florico and Florona stargrass sward canopies on d 1, 7, and 14 of a 2-wk grazing period over five grazing cycles.

Grazing cycle no.	Sampling day 1	7	14	P† L	P† Q
	-------g kg^{-1} ----------				
1	105 a‡	71 b	49 c	0.00	0.26
2	77 c	64 bc	69 ab	0.23	0.04
3	75 c	55 c	65 ab	0.05	0.00
4	66 c	63 bc	76 b	0.52	0.02
5	92 b	87 a	79 a	0.02	0.04
SE§	4	4	3		

† Probability for sampling day effects, linear (L) or quadratic (Q).

‡ Means in a column within sampling day followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ Standard error of the mean.

Pregraze Canopy. Herbage mass of the top and middle layers did not differ between grasses (Table 4-7). Herbage mass of the bottom layer was greater for Florona than for Florico and Callie 35-3. This difference may be due to the dense forming habit of the Florona stargrass sward. There was no difference between the top and the middle canopy layers of Callie 35-3 and Florico. However, HM of the middle layer of Florona, unlike Callie 35-3 and Florico was greater than the top layer, this may partly account for the higher postgraze HM of Florona pastures in Chapter III. Herbage mass of the bottom layer was greater than the upper two layers of all grasses.

Dead HM did not differ in the top layer between grasses (Table 4-7). Florona had the highest dead HM in the middle and bottom layers, probably due to the higher FOF compared to Callie 35-3. The higher dead HM in canopies of Florona may be the cause of the lower whole layer IVOMD compared to Callie 35-3 and Florico (Table 4-4). The dense sward forming habit of Florona compared to Florico and Callie 35-3, might have resulted in shading, and consequently death of leaves lower in the canopy, hence the higher dead HM. However, all grass entries had 2 to 3 times more dead HM in the bottom than the upper layers.

Percent leaf in the top and middle layers did not differ among grass entries (Table 4-7). However, percentage of leaf in the bottom layer of Callie 35-3 was greater than

Table 4-7. Mean herbage mass and leaf composition of top, middle and bottom horizontal sward canopy layers of Callie 35-3 bermudagrass, Florico and Florona stargrasses before grazing.

	Grass			
Layer	Callie 35-3	Florico	Florona	SE†
	--------Herbage mass, kg ha $^{-1}$--------			
		Whole-layer		
Top‡	444 a B§	640 a B	868 a C	56
Middle	718 a B	835 a B	1265 a B	63
Bottom	1080 c A	1300 b A	1668 a A	98
		Dead		
Top	18 a B	62 a B	87 a B	15
Middle	84 b B	75 b B	243 a B	16
Bottom	230 b A	258 b A	473 a A	21
	----------Leaf, % ----------			
Top	56 a A	62 a A	54 a A	5
Middle	37 a B	50 a B	36 a B	7
Bottom	37 a B	28 ab C	17 b C	9

† Standard error of mean.

‡ Top = > 300 mm, middle = 200 to 300 mm. bottom = 100 to 200 mm.

§ Means in a row followed by the same lowercase letter(s), and means in a column followed by the same uppercase letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

Florona. This may partly account for the relatively lower whole-canopy digestibility of Florona. Leaf percentage in the top layer was 10 percentage units higher or more than the middle layer for all grass entries . The leaf composition in the middle and bottom layers of Callie 35-3 did not differ. However, the bottom layer of Florico and Florona contained less leaves than the middle layer.

The IVOMD of the top, middle, and bottom layers of Callie 35-3 and Florico were greater than Florona (Table 4-8), partly due to the higher dead HM in Florona. Whole-layer IVOMD for the top and middle layers was generally greater than the bottom layer, due to higher content of dead and stem material in the bottom layer. Leaf IVOMD of Florona in all layers was lower compared to Callie 35-3 and Florico (Table 4-8). There was no difference in IVOMD of leaf between layers for all grass entries. The IVOMD of Florona stems in the bottom layer was lower than Callie 35-3 and Florico. The stem component in the top and middle layers tended to be more digestible than the bottom layer. This may be due to higher cell wall contents of stem in the more mature bottom layer. The IVOMD of dead material in the top and middle layers did not differ between grass entries and layers. The IVOMD of dead material in the bottom layer tended to be greater for Florico and Callie 35-3 grasses than Florona.

Table 4-8. Mean in vitro organic matter disappearance of top, middle and bottom horizontal sward canopy layers of Callie 35-3 bermudagrass, Florico and Florona stargrasses before grazing.

Layer	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- g kg^{-1} ----------			
		Whole-layer		
Top‡	598 a A§	620 a A	558 b A	13
Middle	566 a AB	590 a A	483 b B	15
Bottom	510 a B	482 a B	397 b C	16
		Leaf		
Top	611 ab A	625 a A	558 b A	19
Middle	610 a A	629 a A	549 b A	14
Bottom	580 a A	609 a A	532 b A	13
		Stem		
Top	552 a A	559 a A	579 a A	14
Midlle	535 a A	555 a A	524 a B	10
Bottom	499 a B	500 a B	418 b C	12
		Dead		
Top	309 a A	310 a A	295 a A	12
Middle	304 a A	311 a A	282 a A	11
Bottom	297 b A	315 a A	264 c B	12

† Standard error of mean.

‡ Top = > 300 mm, middle = 200 to 300 mm, bottom = 100 to 200 mm.

§ Means in a row followed by the same lowercase letter(s), and means in a column followed by the same uppercase letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

Significant layer x cycle interactions were detected for whole layer, leaf, and dead HM for the pregraze canopy (Table 4-9). The HM of the whole-layer was greater for the bottom layer than the top layer in cycles 1, 2 and 5. Whole layer HM for the top layer was lower than the middle and bottom layers in cycles 1 and 5. The bottom layer HM did not change with cycles whereas top layer mass decreased in cycle 5. The HM of the leaf and dead components in the canopy were generally greater for the bottom layer than the top layer. The higher dead material in the bottom layer may be partly attributed to shading of lower leaves, cattle trampling, and standing water during summer conditions, resulting in higher rates of senescence in the lower leaves. Dead HM in the top and bottom layers did not differ with cycle.

The top layer had higher leaf component in cycles 2 and 4 than the bottom layer (Table 4-10). There was no difference between cycles for percentage leaf in the top layer. Percentage of leaf in the middle layer was greater during cycles 1, 4, and 5. Percentage leaf in the bottom layer was lowest in cycles 2 and 4. Percentage of stem in the top layer was lower than the middle and bottom layers in cycles 2 and 3. The composition of stem in the top layer was greater in cycle 1 due to inflorescence and least in cycle 5. Stem composition in the middle layer was greater in cycles 2 and 3. The variation in stem within cycle could be

Table 4-9. Mean herbage mass of top, middle, and bottom horizontal sward canopy layers of Callie 35-3 bermudagrass, Florico and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Layer†			SE‡
	Top	Middle	Bottom	
	--- kg ha^{-1} ---			
	Whole-layer			
1	639 c A§	696 b B	1213 a A	91
2	660 b A	985 ab AB	1418 a A	70
3	1121 a A	1280 a A	1344 a A	75
4	755 a A	999 a AB	1391 a A	61
5	88 c B	735 b B	1380 a A	53
	Leaf			
1	309 b A	316 b B	557 a AB	45
2	213 b AB	505 a AB	624 a AB	70
3	365 b A	694 a A	785 a A	75
4	325 b A	307 b B	537 a AB	56
5	41 c B	244 ab B	407 a B	53
	Dead			
1	0 b A	4 b B	49 a A	14
2	95 b A	286 ab A	485 a A	24
3	89 b A	96 b B	287 a A	35
4	83 b A	169 b AB	460 a A	31
5	9 b A	114 b AB	325 a A	53

† Top = > 300 mm, middle = 200 to 300 m, bottom = 100 to 200 mm.

‡ Standard error of mean.

§ Means in a row followed by the same lowercase letter(s), and means in a column followed by the same uppercase letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

Table 4-10. Mean component composition of top, middle, and bottom horizontal sward canopy layers of Callie 35-3 bermudagrass, Florico and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Layer†			SE‡
	Top	Middle	Bottom	
	--- % ---			
	Leaf			
1	49 a A§	54 a A	38 a AB	4
2	60 a A	33 b B	18 b C	2
3	64 a A	34 a B	22 a AB	5
4	53 a A	43 a A	16 b C	4
5	68 a A	43 a A	41 a A	3
	Stem			
1	49 a A	40 a AB	44 a AB	5
2	29 b BC	53 a A	44 a AB	7
3	32 b BC	54 a A	58 a A	5
4	36 a AB	38 b AB	41 a AB	3
5	21 a C	28 a B	31 a B	3
	Dead			
1	0 b A	1 b B	3 a A	4
2	9 b A	13 a A	34 a A	2
3	3 b A	7 b B	19 a A	5
4	10 a A	16 a A	32 a A	3
5	6 a A	12 a A	27 a A	5

† Top = > 300 mm, middle = 200 to 300 mm, bottom = 100 mm to 200 mm.

‡ Standard error of mean.

§ Means in a row followed by the same lowercase letter(s), and means in a column followed by the same uppercase letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

attributed to changes in climatic conditions with cycle, as well as on set of flowering at different times of the season, since flower heads were included in the stem fraction.

Percentage of dead material in the bottom layer was higher than the top layer in cycles 1, 2, and 3 (Table 4-10). Composition of dead material in cycles 4 and 5 did not differ between layers. The percentage dead material in the top and bottom layers did not differ between cycles.

Mean CP concentration of whole-layer tended to be higher for the top than the middle and bottom layers in cycles 1 to 4. Leaf CP concentration did not differ between layers in any cycles except cycle 1 (Table 4-11). Stem CP in the top layer was greater than the middle and bottom layers in cycles 1 and 4, partly because the top layer may contain younger stems and meristematic tissues compared with the bottom layer.

Mean IVOMD of whole-layer and stem fractions in the top layer differed significantly from the bottom layer in all cycles (Table 4-12), due to higher leaf to stem ratio and lower dead HM in the top layer. The IVOMD of leaf in the top and middle layers was greater than the bottom layer in cycle 1. The stem component in the top and middle layers tended to be more digestible than the stem in the bottom layer (Table 4-12), this may be partly due to higher cell wall content of the older stem material in the bottom layer.

Table 4-11. Mean crude protein concentration of top, middle, and bottom horizontal sward canopy layers of Callie 35-3 bermudagrass and Florico and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Layer†			SE‡
	Top	Middle	Bottom	
	---------- g kg^{-1} ----------			
	Whole-layer			
1	153 a A§	120 b B	100 c A	9
2	106 a B	76 b C	56 c B	7
3	96 a B	80 b C	65 b B	7
4	93 a B	80 b C	56 c B	6
5	150 a A	140 a A	100 b A	5
	Leaf			
1	158 a B	145 a B	115 b B	4
2	128 a C	120 a B	115 a B	7
3	113 a C	123 a B	121 a B	5
4	113 a C	115 a B	115 a B	6
5	216 a A	198 a A	168 a A	5
	Stem			
1	113 a A	98 b A	70 b AB	4
2	81 a B	71 a BC	50 b C	4
3	78 a B	71 ab B	63 b B	5
4	70 a B	61 b C	48 b C	3
5	100 a A	83 ab AB	73 b A	5

† Top = > 300 mm, middle = 200 to 300 mm, bottom = 100 to 200 mm.

‡ Standard error of mean.

§ Means in a row followed by the same lowercase letter(s), and means in a column followed by the same uppercase letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

Table 4-12. Mean in vitro organic matter disappearance in top, middle, and bottom horizontal sward canopy layers of Callie 35-3 bermudagrass and Florico and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Layer†			SE‡
	Top	Middle	Bottom	
	---------- g kg^{-1} ----------			
	Whole-layer			
1	646 a A§	603 ab A	565 b A	11
2	568 a B	508 a B	441 b B	8
3	555 a B	511 ab B	455 b B	10
4	590 a B	526 a B	386 b B	9
5	601 a AB	581 a AB	467 b B	5
	Leaf			
1	615 a AB	600 a AB	536 b B	14
2	548 a C	546 a B	540 a B	8
3	576 a BC	575 a B	555 a AB	11
4	601 a BC	603 a AB	588 a AB	15
5	671 a A	651 a A	628 a A	7
	Stem			
1	576 a A	581 a A	518 b A	10
2	571 a A	536 a AB	458 b AB	7
3	551 a A	523 a B	471 b AB	11
4	555 a A	515 a B	433 b B	13
5	565 a A	533 ab AB	480 c AB	11

† Top = > 300 mm, middle = 200 to 300 mm, bottom = 100 to 200 mm.

‡ Standard error of mean.

§ Means in a row followed by the same lowrcase letter(s), and means in a column followed by the same uppercase letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

The higher IVOMD and CP in the top layer compared to the bottom layer may be attributed to greater leaf to stem ratio in the top layer.

Ingestive Behavior

There were grass x cycle ($P < 0.04$), grass x sampling day ($P < 0.01$) and cycle x sampling day ($P < 0.05$) interactions for bite weight. Bite weight did not differ among grass entries during cycles 1, 2, and 3 (Table 4-13). Bite weight of steers on Callie 35-3 was less than Florico and Florona during cycles 4 and 5, partly due to the lower whole canopy HM of Callie 35-3, especially in cycle 5. Mean bite weight of steers on grass entries dropped from cycle 1 to cycle 2, increased in cycle 3 and dropped again in cycles 4 and 5. Mean bite weight for steers on Callie 35-3 was smaller than Florico and Florona on d 1 (Table 4-14). Mean bite weight did not differ among grass entries on d 7, however, bite weight was highest for Florico on d 14. Bite weight of steers on Callie 35-5 and Florico declined linearly from d 1 to 14, while both linear and quadratic effects were obtained for Florona. The decline in bite weight was a direct consequence of the decline in whole canopy HM and the decrease in leaf to stem ratio.

Bite weight generally declined linearly or linearly and quadratically from d 1 to 14 within a grazing cycle (Table 4-15) due to the decline in HM of the whole canopy, and leaf mass in the top and middle layers of the canopy. Bite

Table 4-13. Mean bite weight for steers on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- g DM bite^{-1} ----------			
1	0.91 a‡	0.94 a	0.92 a	0.11
2	0.51 a	0.67 a	0.64 a	0.10
3	0.85 a	0.89 a	0.80 a	0.12
4	0.50 b	0.75 a	0.76 a	0.07
5	0.44 b	0.60 a	0.59 a	0.05
$LSD_{0.05}$§	0.19	0.17	0.22	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ LSD for comparison between cycles for each grass.

Table 4-14. Mean bite weight for esophageal fistulated steers grazing Callie 35-3 bermudagrass, Florico and Florona stargrasses at d 1, 7, and 14 of a 2-wk grazing period.

Sampling day	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- g DM bite^{-1} ----------			
1	0.85 b‡	0.89 ab	1.10 a	0.07
7	0.59 a	0.73 a	0.64 a	0.05
14	0.48 b	0.68 a	0.51 b	0.04
	---------- P-value of F test -----			
L§	0.01	0.01	0.01	
Q	0.31	0.37	0.01	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

§ L = linear, Q = quadratic.

Tables 4-15. Mean bite weight of esophageal fistulated steers on d 1, 7, and 14 of a 2-wk grazing period over five grazing cycles.

Grazing cycle no.	Sampling day			p†	
	1	7	14	L	Q
	----- g DM bite^{-1} ------				
1	1.20	0.93	0.64	0.01	0.04
2	0.79	0.57	0.45	0.01	0.03
3	1.20	0.68	0.68	0.03	0.19
4	0.90	0.59	0.53	0.01	0.05
5	0.65	0.49	0.48	0.01	0.23
$LSD_{0.05}$‡	0.18	0.11	0.14		

† Probability for sampling day effect, L = linear, Q = quadratic.

‡ LSD for comparison between cycles on a sampling day.

weight generally dropped from cycle 1 to cycle 5 for all sampling days. Bite weight was related to HM of leaf in the pregraze canopy (Callie 35-3, $r = 0.60$; Florico, $r = 0.82$, Florona $r = 0.64$; $n = 60$), which further explains the decline in bite weight with the grazing season.

The drop in bite weight with season is consistent with the findings of Leaver (1986). Mean bite weight ranged from 0.44 to 0.91, 0.60 to 0.94, and 0.59 to 0.92 g DM bite^{-1} for steers grazing Callie 35-3, Florico, and Florona, respectively, over the season (Table 4-13). These ranges of values are lower than those reported by Brown et al. (1987b) because the present study covered an entire grazing season with lower FOF especially toward the end of the season. However, the ranges of bite weight in this study fall within some of the ranges reported in the literature (Chacon et al., 1978; Kanyama-Phiri and Conrad, 1986; Moore and Sollenberger, 1986).

There were grass x cycle ($P < 0.04$), grass x sampling day ($P < 0.04$) and cycle x sampling day ($P < 0.03$) interactions for biting rate. Except for cycle 3, biting rate was generally lower on Florico than Callie 35-3 and Florona (Table 4-16), probably due to manipulation of Florico forage prior to biting possibly due to leaf-stem composition and the pubescence on this grass. Perhaps the highly stoloniferous growth habit of Florico or steer compensation for larger bit weight on Florico could also be contributing

Table 4-16. Mean biting rate for steers on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- bites min.$^{-1}$ ----------			
1	33 a‡	26 b	28 ab	1.8
2	44 a	28 b	37 a	2.5
3	31 a	25 a	32 a	2.5
4	39 a	25 b	38 a	3.3
5	46 a	36 b	48 a	3.1
$LSD_{0.05}$§	7	6	6	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different ($P > 0.05$) according to Duncan's Multiple Range Test.

§ LSD for comparison between cycles for each grass.

factors. Biting rate increased from cycle 1 to cycle 2 for Callie 35-3 and Florona, and dropped from cycle 2 to 3, after which it increased to a maximum at cycle 5 as FOF became limiting. Mean biting rate ranged from 31 to 46, 25 to 36, and 28 to 48 bites min^{-1} for Callie 35-3, Florico and Florona, respectively. The variation in biting rate with cycle is a direct reflection of the variation in HM of the whole canopy especially leaf mass in the upper two layers.

Biting rate was lower for steers grazing Florico on d 1, 7, and 14, compared with Callie 35-3 and Florona (Table 4-17). There was a linear decline in biting rate for steers on Callie 35-3 pastures from d 1 to 14, possibly due to a decline in leaf HM. Mean biting rate declined linearly and quadratically on Florico and Florona. Mean biting rate generally declined linearly within a cycle (Table 4-18), due to decline in total canopy HM, and decreasing leaf to stem ratio in the top and middle canopy. Biting rate was positively related to leaf herbage mass in the pregraze canopy (Callie 35-3, $r = 0.51$; Florico, $r = 0.49$; Florona $r = 0.54$; $n = 60$). These biting rate values are in agreement with the literature (Moore and Sollenberger, 1986, Brown et al., 1987b). Brown et al. (1987a) and Dougherty et al. (1987) reported linear and quadratic decline in biting rate from pregraze to postgrazing period.

Table 4-17. Mean biting rate for esophageal fistulated steers grazing Callie 35-3 bermudagrass, Florico and Florona stargrasses at d 1, 7, and 14 of a 2-wk grazing period.

Sampling day	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- bites min^{-1} ----------			
1	41 a‡	31 b	41 a	2.5
7	40 a	32 b	39 a	2.0
14	34 a	21 b	29 a	2.1
	---------- P-value of F test -----			
L§	0.02	0.01	0.01	
Q	0.31	0.01	0.02	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

§ L = linear, Q = quadratic.

Table 4-18. Mean biting rate of esophageal fistulated steers on d 1, 7, and 14 of a 2-wk grazing period over five grazing cycles.

Grazing cycle no.	Sampling day			P†	
	1	7	14	L	Q
	----- bites min^{-1} ------				
1	32	31	24	0.05	0.36
2	43	33	34	0.04	0.11
3	33	33	22	0.01	0.17
4	37	40	24	0.04	0.04
5	44	48	38	0.03	0.05
$LSD_{0.05}$‡	8	5	6		

† Probability for sampling day effect, L = linear, Q = quadratic.

‡ LSD for comparison between cycles on a sampling day.

There were grass x cycle ($P < 0.04$), grass x sampling day ($P < 0.01$) and cycle x sampling day ($P < 0.05$) interactions for intake rate. Mean intake rates did not differ among grass entries in cycles 1, 2, 3, and 5 (Table 4-19). Intake rate was higher ($P < 0.05$) on Florona than on Callie 35-3 and Florico in cycle 4, possibly due to higher biting rate and bite weight of Florona, since intake was estimated from the product of biting rate and bite weight. Intake rate was higher for Florona on d 1 than on Florico and Callie 35-3 (Table 4-20). The lower intake rate on Florico despite its higher bite weight may be attributed to the lower biting rate and possibly the leaf and stem pubescence, while the lower intake rate of Callie 35-3 may be attributed to the lower bite weight. Intake rate did not differ among grass entries on d 7 and 14 (Table 4-20). Rate of intake declined linearly from d 1 to 14 of grazing on all grass entries, due to the decline in bite weight and biting rate from d 1 to 14, which is consistent with the results of Brown et al. (1987b). Mean intake rate generally declined linearly within a grazing cycle (Table 4-21), possibly due to a decline in biting rate and bite weight. Mean intake rates ranged from 19 to 30, 17 to 25, and 25 to 31 on Callie 35-3, Florico, and Florona (Table 4-19).

During d 1 of sampling, the canopy had a high proportion of leaves with little stem and dead material in the top and middle layers, therefore steers grazed with less

Table 4-19. Mean intake rate for steers on rotationally-grazed Callie 35-3 bermudagrass, Florico and Florona stargrasses over five grazing cycles.

Grazing cycle no.	Grass			
	Callie 35-3	Florico	Florona	SE†
	-------- g DM $min.^{-1}$ ----------			
1	30 a‡	25 a	27 a	4.3
2	23 a	17 a	25 a	3.3
3	27 a	22 a	26 a	5.1
4	19 b	18 b	31 a	3.9
5	19 a	21 a	29 a	3.3
$LSD_{0.05}$§	9	7	11	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different($P > 0.05$) according to Duncan's Multiple Range Test.

§ LSD for comparison between cycles for each grass.

Table 4-20. Mean intake rate for esophageal fistulated steers grazing Callie 35-3 bermudagrass, Florico and Florona stargrasses at d 1, 7, and 14 of a 2-wk grazing period.

Sampling day	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- g DM min^{-1} ----------			
1	33 b‡	26 b	43 a	2.7
7	23 a	23 a	25 a	1.6
14	15 a	13 a	15 a	1.0
	---------- P-value of F test -----			
L§	0.01	0.01	0.01	
Q	0.79	0.18	0.06	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

§ L = linear, Q = quadratic.

Table 4-21. Mean intake rate of esophageal fistulated steers on d 1, 7, and 14 of a 2-wk grazing period over five grazing cycles.

Grazing cycle no.	Sampling day			P†	
	1	7	14	L	Q
	------- g DM min^{-1} --------				
1	38	29	15	0.01	0.18
2	32	19	14	0.04	0.32
3	39	23	13	0.05	0.23
4	33	23	12	0.05	0.41
5	28	23	17	0.04	0.17
$LSD_{0.05}$‡	10	5	3		

† Probability for sampling day effect, L = linear, Q = quadratic.

‡ LSD for comparison between cycles on a sampling day.

selectivity. During d 14, however, steers might have been more selective due to decreasing HM, leaf to stem ratio, and sward height, resulting in the observed declines in bite weight, rate of biting, and rate of intake from d 1 to 14.

Day of sampling interacted with grass entry ($P < 0.05$) and grazing cycle ($P < 0.01$) for CP concentration in the diet selected by steers. Steers on Callie 35-3 and Florona seemed to have selected diets that were higher in CP concentration than those on Florico on d 1 of grazing (Table 4-22). Mean CP concentration in the diet was similar between grass entries on d 14 reflecting the lack of selectivity on d 14. Mean CP concentration in the diet declined linearly and quadratically from d 1 to 14 for all grass entries. Mean CP in the diet decreased linearly from d 1 to 14 in all cycles (Table 4-23).

Steers on Callie 35-3 seemed to have selected diets higher in IVOMD on d 1 (Table 4-24) compared to those on Florico and Florona. The IVOMD of diet selected by steers on d 14 did not differ among grass entries. Response of IVOMD to sampling day was linear and quadratic for Callie 35-3 and Florona, and linear for Florico. The IVOMD of diet declined linearly from day 1 to 14 within all grazing cycles (Table 4-25).

The decline in CP concentration and IVOMD from d 1 to d 14 may be associated with decreasing leaf to stem ratio and increasing dead HM in the grazed canopy. The decrease

Table 4-22. Mean concentration of crude protein in esophageal extrusa of steers grazing Callie 35-3 bermudagrass, Florico and Florona stargrasses at d 1, 7,and 14 of a 2-wk grazing period.

Sampling day	Grass			
	Callie 35-3	Florico	Florona	SE†
	---------- g kg^{-1} ----------			
1	163 a‡	143 b	158 a	4.9
7	104 ab	100 b	112 a	3.2
14	94 a	83 a	92 a	3.9
$LSD_{0.05}$§	15	12	12	
	---------- P-value of F test -----			
L¶	0.01	0.01	0.01	
Q	0.01	0.01	0.01	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

§ LSD for comparison between sampling days for each grass.

¶ L = linear, Q = quadratic.

Tables 4-23. Mean concentration of crude protein in esophageal extrusa of steers on d 1, 7, and 14 of a 2-wk grazing period over five grazing cycles.

Grazing cycle no.	Sampling day			P†	
	1	7	14	L	Q
	--------- g kg^{-1} --------				
1	167	99	72	0.01	0.19
2	152	101	102	0.04	0.34
3	141	95	76	0.05	0.11
4	139	104	98	0.04	0.25
5	174	126	100	0.03	0.08
$LSD_{0.05}$‡	13	7	9		

† Probability for sampling day effect, L = linear, Q = quadratic.

‡ LSD for comparison between cycles on a sampling day.

Table 4-24. Mean in vitro organic matter disappearance (IVOMD) in esophageal extrusa of steers grazing Callie 35-3 bermudagrass, Florico and Florona stargrasses at d 1, 7, and 14 of a 2-wk grazing period.

Sampling day	Grass			
	Callie 35-3	Florico	Florona	SE†
	----------IVOMD g kg^{-1} ----------			
1	661 a‡	623 b	620 b	8.1
7	541 a	545 a	507 b	9.8
14	496 a	487 a	475 a	7.1
$LSD_{0.05}$§	24	32	23	
	---------- P-value of F test -----			
L¶	0.01	0.01	0.01	
Q	0.01	0.34	0.01	

† Standard error of mean.

‡ Means in a row followed by the same letter(s) are not different (P > 0.05) according to Duncan's Multiple Range Test.

§ LSD for comparison between sampling days for each grass.

¶ L = linear, Q = quadratic.

in selectivity from d 1 to d 14 of grazing might have caused ingestion of greater proportions of stem and dead material, resulting in lower CP and IVOMD in the diet from d 1 to d 14. Brown et al. (1987b) reported an increase in dead material in the extrusa of steers grazing stargrass from pre- to postgrazing periods.

Table 4-25. Mean in vitro organic matter disappearance (IVOMD) in esophageal extrusa of steers on d 1, 7, and 14 of a 2-wk grazing period over five grazing cycles.

Grazing cycle no.	Sampling day			P†	
	1	7	14	L	Q
	----- IVOMD g kg^{-1} ------				
1	665	555	482	0.01	0.26
2	606	495	487	0.03	0.07
3	648	537	502	0.04	0.19
4	609	501	474	0.01	0.16
5	643	566	482	0.01	0.06
$LSD_{0.05}$‡	24	19	16		

† Probability for sampling day effect, L = linear, Q = quadratic.

‡ LSD for comparison between cycles on a sampling day.

CHAPTER V
SUMMARY AND CONCLUSIONS

'Florico' and 'Florona' stargrasses (C. nlemfuensis Vanderyst var. nlemfuensis) and Callie hybrid 35-3 (C. dactylon (L) Pers.) an experimental bermudagrass are superior in dry matter (DM) yield and persistence to the industry standard Ona, stargrass (C. nlemfuensis Vanderyst var. nlemfuensis) under grazing in south Florida. Yet little information is available on forage production and animal performance on pastures of Callie 35-3 bermudagrass and Florico and Florona stargrasses. The objectives of this study were to compare 1) forage production, nutritive value, animal performance, and total nonstructural carbohydrate trends of Callie 35-3 bermudagrass, and Florico and Florona stargrasses under rotational grazing, 2) canopy characteristics of the three grasses, and 3) ingestive behavior and quality of diet selected by steers grazing the three grasses.

Four 0.5-ha pastures of each grass were divided into three 0.17-ha units and were rotationally grazed at a stocking rate of about eight 240-kg steers ha^{-1}. A modified 'put-and-take' stocking system was used to adjust animal numbers to prevent build up of forage-on-offer. Herbage

within four randomly selected 0.5 m^2 quadrats were cut in 100 mm stratified horizontal layers to study canopy characteristics. Esophageally fistulated Brahman-cross steers were used to sample pastures on d 1, 7, and 14 of a 2-wk grazing period. Seasonal herbage availability differed between grass entries, with a 2-yr average of 13, 17, and 18 Mg ha^{-1} for Callie 35-3, Florico, and Florona, respectively. Concentration of crude protein did not differ between grass entries and ranged from 74 to 101 g kg^{-1}. In vitro organic matter disappearance (IVOMD) differed between grass entries ranging between 526 to 555, 566 to 571, and 520 to 533 g kg^{-1} for Callie 35-3 bermudagrass, Florico, and Florona stargrasses, respectively. Carrying capacity ranged for 1332 and 1573 steer d ha^{-1} and was higher for Florico and Florona than Callie 35-3. Total nonstructural carbohydrates in the root-crown region of all grass entries declined as the season advanced. Herbage allowance and herbage disappearance were greater for Florico and Florona stargrasses than Callie 35-3 bermudagrass. Average gain differed between grasses with a range of 0.30 to 0.48, 0.43 to 0.62, and 0.37 to 0.49 kg d^{-1} for Callie 35-3, Florico and Florona, respectively. Beef gain ha^{-1} of 495 kg on Callie 35-3 pastures was lower than 742 and 655 kg on pastures of Florico and Florona stargrasses, respectively.

Herbage mass of the whole canopy and percentage of leaf in the canopy decreased while percentage of stem increased

from d 1 to d 14 of grazing. Herbage mass of the bottom (100 to 200 mm) canopy layer was greater for Florona than Callie 35-3 and Florico. Florona had the highest dead herbage mass in the middle (200 to 300 mm) and bottom layers which resulted in lower IVOMD of the whole sward canopy compared with Florico and Callie 35-3 bermudagrass. Percentage of leaf in the top (> 300 mm) layers of all grass entries was 10 percentage units or more than that of the middle and bottom layers.

The IVOMD of the top, middle, and bottom layers of Callie 35-3 and Florico were higher than Florona. The IVOMD of Florona leaf in all layers was lower than that of Callie 35-3 and Florico. The stem fractions in the top and middle canopy layers tended to be of higher digestibility than the stem in the bottom layer for all grass entries.

Bite weight of steers grazing all three grass entries declined from d 1 to d 14. Mean bite weight ranged from 0.44 to 0.91, 0.60 to 0.94, and 0.59 to 0.92 g DM $bite^{-1}$ for steers grazing Callie 35-3, Florico, and Florona, respectively. Biting rate of steers declined from d 1 to d 14 of grazing. Biting rate was generally slower on Florico compared to Callie 35-3 and Florona. Mean biting rate ranged from 31 to 46, 25 to 36, and 28 to 48 bites min^{-1} for Callie 35-3, Florico, and Florona, respectively.

Intake rate declined from d 1 to d 14 of grazing for all grass entries, possibly due to the decline in bite

weight and biting rate. Mean intake rate ranged from 19 to 30, 17 to 25, and 25 to 29 g DM min^{-1} for Callie 35-3, Florico, and Florona, respectively.

Bite weight, biting rate, and intake rate were positively correlated to leaf mass in the top canopy. Thus, grazing management practices which increase leaf to stem ratio in the grazed horizon may result in increased bit weight and consequently higher animal performance. Furthermore, the decline in bite weight, biting, and intake rate during the grazing period suggest that shorter grazing periods may result in heavier bites, faster biting and higher intake rates and consequently higher animal gains from all the grass entries in this study. Further research on the effect of length of the grazing period on ingestive behavior would be desirable.

Results of the study indicate Callie 35-3 bermudagrass would primarily fit in a pasture system to provide early grazing and perhaps quality hay with less steminess than the stargrasses. Florico stargrass was higher in quality and could be used for young growing cattle such as replacement heifers. Florona stargrass may be better suited to high production needs with mature cattle such as the cow-calf herd.

APPENDIX

Table A-1. Manufacturer's† guaranteed elemental analysis of mineral supplement.

Mineral	Level
	%
Ca	> 12.00
P	< 12.00
Na Cl	> 25.00
Fe	> 1.00
Cu	> 0.13
Co	> 0.03
Mn	> 0.05
Zn	> 0.10
F	< 0.18

†NOTE: Manufactured by Lakeland Cash Feed Co., Lakeland, Florida.

Table A-2. Trends in total nonstructural carbohydrates concentration in root-crown area of Callie 35-3 bermudagrass, Florico, and Florona stargrass pastures in 1986.

Sampling dates		Callie 35-3	Florico	Florona
		----------g kg^{-1}----------		
May	2	118	93	100
	16	92	58	55
	23	84	59	61
	30	91	91	71
June	6	99	91	71
	13	77	60	72
	20	57	38	40
	27	65	47	44
July	3	64	52	58
	10	72	55	66
	17	71	68	63
	25	54	42	39
Aug.	1	47	58	48
	8	68	56	64
	15	77	61	61
	22	76	77	64
	29	64	62	55
Sept.	4	38	36	32
	11	37	49	56
	18	63	57	49
	25	57	70	57
Oct.	3	65	65	57
	10	65	64	54
	17	43	55	43
	24	49	45	42
	31	50	52	46
Nov.	7	58	57	55
	14	58	54	50
	21	71	51	48
	25	71		

Table A-3. Seasonal trends in total nonstructural carbohydrates (TNC) pool* in root-crown area of rotationally-grazed Callie 35-3 bermudagrass, Florico, and Florona stargrass pastures in 1987.

Sampling dates		Callie 35-3	Florico	Florona
		----------TNC, g ----------		
May	19	9.6	12.4	11.2
	28	11.1	16.7	15.4
June	4	16.4	19.6	18.6
	11	15.5	21.0	14.6
	17	19.3	24.4	15.5
	25	12.2	19.1	15.7
July	3	13.2	15.3	13.1
	10	12.1	12.4	11.8
	16	10.5	16.2	12.8
	24	8.0	15.0	10.3
	30	8.6	18.5	17.1
Aug.	6	9.1	7.2	12.3
	13	11.3	17.4	13.2
	19	15.0	17.6	20.6
	27	9.6	14.4	13.7
Sept.	4	12.5	14.1	11.7
	11	9.9	15.3	8.6
	18	9.9	17.5	10.7
	25	9.1	9.8	11.4
Oct.	2	11.2	15.0	10.7
	9	11.6	14.4	11.0
	16	8.8	10.6	11.0
	23	11.2	14.3	12.7
	30	16.2	15.6	15.7
Nov.	6	13.5	20.0	11.6
	13	11.9	16.1	12.2
	20	8.4	12.2	13.5
	27	13.6	16.9	12.6
Dec.	2	14.8	16.9	12.0
	10	11.9	19.2	11.9

*TNC pool = TNC concentration x root-crown biomass.

Table A-4. Seasonal trends in total nonstructural carbohydrates in root-crown area of rotationally-grazed Callie 35-3 bermudagrass and Florico, and Florona stargrass pastures in 1987.

Sampling dates		Callie 35-3	Florico	Florona
		----------g kg^{-1}----------		
May	19	66	68	61
	28	69	76	75
June	4	78	77	69
	11	87	79	76
	17	80	76	72
	25	61	51	55
July	3	75	70	62
	10	76	62	64
	16	51	51	49
	24	42	46	44
	30	44	36	40
Aug.	6	47	39	35
	13	38	44	37
	19	49	40	37
	27	36	38	32
Sept.	4	54	52	48
	11	52	36	34
	18	51	48	40
	25	41	34	35
Oct.	2	43	36	31
	9	49	38	33
	16	45	41	38
	23	52	51	52
	30	71	62	68
Nov.	6	66	59	51
	13	64	63	57
	20	55	53	48
	27	62	59	54
Dec.	2	70	63	48
	10	66	60	55

Table A-5. Summary of analysis of variance for ingestive behavior of steer and extrusa crude protein (CP) concentration and in vitro organic matter disappearance (IVOMD) for rotationally-grazed Callie 35-3 bermudagrass, Florico, and Florona stargrass pastures.

Source	Variable				
	Bite wt.	Biting rate	Intake rate	CP	IVOMD
	P-value of F test				
Grass (G)	0.11	0.00†	0.06	0.12	0.05
Day (D)	0.00	0.00	0.00	0.00	0.00
D x G	0.01	0.04	0.00	0.05	0.01
Cycle (C)	0.00	0.00	0.01	0.00	0.00
G x C	0.04	0.04	0.01	0.16	0.06
D x C	0.05	0.03	0.04	0.00	0.00
C x G x P	0.15	0.07	0.12	0.08	0.11

† $P < 0.001$.

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BIOGRAPHICAL SKETCH

Asamoah Larbi was born on the 7th of July, 1956, in Ghana, West Africa. He graduated from Oda Secondary School in September 1976, and received a B.S. degree with a major in animal science from the University of Ghana in 1979.

Asamoah worked with the Ministry of Agriculture, Division of Animal Husbandry. He received an M.S. degree in pasture science from the University of Ghana in November 1982. In December 1982, Asamoah joined the Department of Animal Science, University of Ghana as a lecturer.

In August 1985, he was awarded a Fulbright Scholarship to pursue graduate studies in range science at Oregon State University. He enrolled at the University of Florida in June 1986. He is currently a candidate for the Doctor of Philosophy in agronomy.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Paul Mislevy
Paul Mislevy, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Lynn E. Sollenberger
Lynn E. Sollenberger
Assistant Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. D. Pitman
W. D. Pitman
Associate Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

R. S. Kalmbacher
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. F. Brown
Assistant Professor of Animal Science

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 1989

Jack L. Fry
Dean, College of Agriculture

Dean, Graduate School